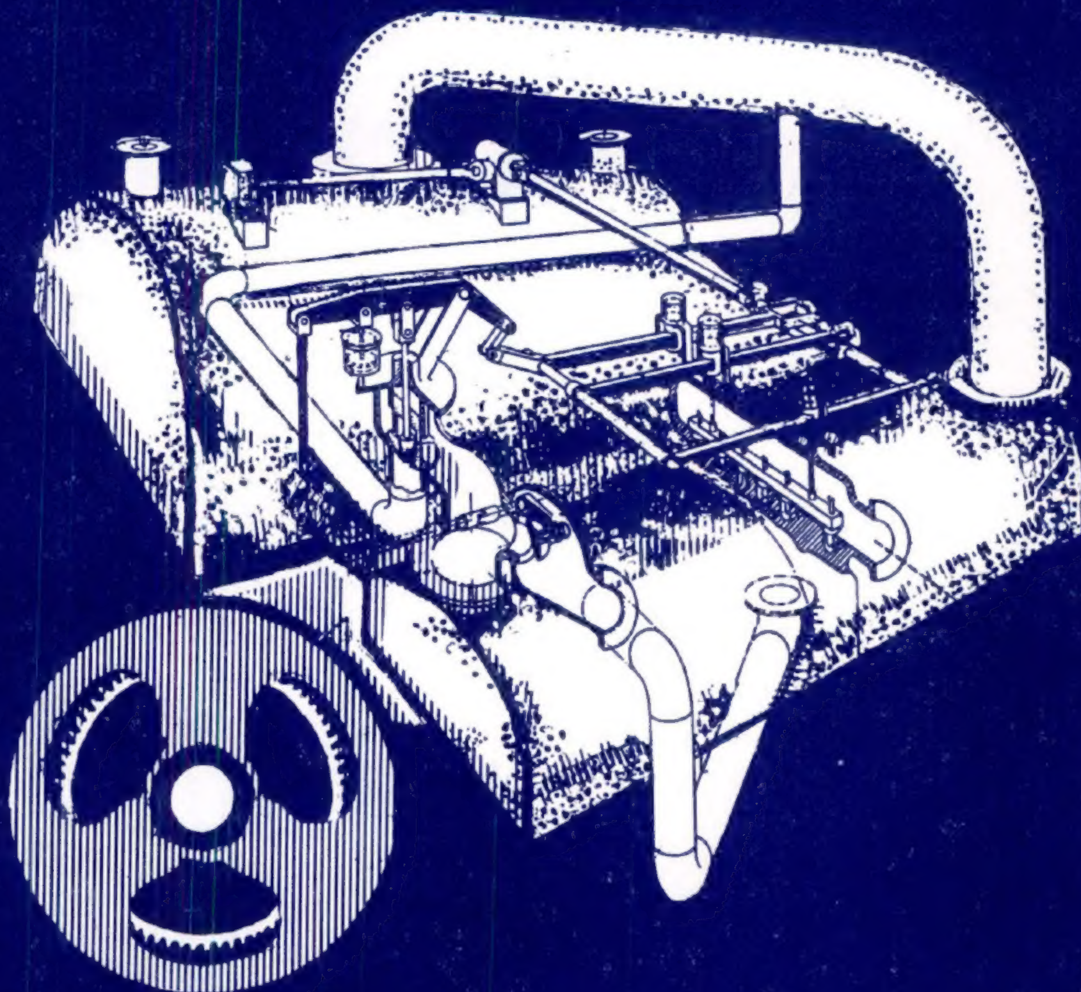

MACHINIST'S MATE 3 & 2

NAVAL TRAINING COMMAND

RATE TRAINING MANUAL NAVTRA 10524-D

PREFACE

The primary purpose of training is to produce a combat Navy which can guarantee victory at sea. This victory is dependent upon the readiness of the personnel aboard. Each individual is assigned tasks to perform dependent upon the needs of the ship. The information in this manual relates to tasks required to meet shipboard needs—tasks that are assigned to personnel aboard ship, serving as a Machinist's Mate Third Class and Machinist's Mate Second Class. This rate training manual provides information related to the duties required to operate and maintain ship propulsion machinery and associated equipment. It is only when we have personnel aboard who can and do perform these tasks efficiently that we will have each ship operating at a high state of readiness and add her contribution essential to victory at sea. When you are assigned duties aboard ship as an MM3 or MM2, you will be expected to have a thorough knowledge of the information contained in this manual. The degree of success of the Navy will depend in part on the ability you possess and the manner in which you perform your assigned duties.

Machinist's Mate 3 & 2, NAVTRA 10524-D was prepared by the Navy Training Publications Detachment, Washington, D.C., for the Chief of Naval Training. Information provided by numerous manufacturers and technical societies is gratefully acknowledged. Technical assistance was provided by the Naval Ship Systems Command, the Naval Development and Training Center, San Diego, and the Service School Command and Naval Examining Center, Great Lakes, Illinois.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CHAPTER 1

PREPARING FOR YOUR JOB

The fleet needs capable men in all ratings because a modern naval force is only as good as the men who man the ships. Even with the most modern equipment, a naval force is almost powerless without competent men to operate and maintain that equipment. Good men are plentiful, but their capability depends chiefly upon their training. The primary purpose of training is to produce a combat Navy which can guarantee victory at sea.

This manual contains information a knowledge of which you need as you continue your training to become more proficient in your job. This knowledge along with the essential experience in the practical aspects of assigned duties should aid you in attaining higher promotional levels in your rating and at the same time assist the Navy in accomplishing its mission.

MM DUTIES AND ASSIGNMENTS

As you progress to each higher promotional level in your rating, you will be required to gradually assume greater responsibility for assigned tasks which become increasingly more difficult. These tasks will vary from one operation to the next, and from ship to ship. Your job is to become familiar with all aspects of the MM rating, but this will require continued efforts to gain more experience in, and knowledge of, assigned tasks.

Machinist's Mates are assigned to all types of ships. Most Machinist's Mates are assigned to "M" Division where they operate and maintain ship propulsion machinery and associated equipment such as: pumps, distilling plants, compressors, valves, oil purifiers, heat exchangers, governors, reduction gears, shafts, and shaft bearings.

Machinist's Mates who are assigned duties other than in enginerooms maintain and repair machinery such as: steering engines, anchor windlasses, cranes, winches, elevators, laundry equipment, galley equipment, and air conditioning and refrigeration equipment.

The nature of the Machinist's Mates duties depends largely on the type of ship or station to which he is assigned. Repair ships and tenders furnish other ships with spare parts, repairs, and other services that are beyond the facilities of the ship's crew. The duties of a Machinist's Mate assigned to a repair ship or tender may consist mainly of repairs and other services to ships assigned to the tender or repair ship. As a Machinist's Mate, you may choose an area of specialization.

The Machinist's Mate must have a good working knowledge of the basic principles of naval engineering. If you are lacking in this area, the manuals listed in the Bibliography for Advancement Study, NAVTRA 10052 (revised) will be helpful. You will gain the necessary practical experience for advancement through performance of your daily duties. Increasing your technical knowledge, however, will require some reading and studying in your spare time.

Upon advancement to MM3, you will be graded on your leadership and supervisory ability as well as your ability to perform your technical duties. Study the leadership principles and techniques discussed in Military Requirements for Petty Officers 3 & 2, NAVPERS 10056-C. Additional material concerning leadership for petty officers is available to you as a result of the Navy leadership program. As you study the material containing leadership traits, keep in mind that probably none of our most successful leaders possessed all of these traits to a maximum degree, but a weakness in some traits was more than compensated for by strength in others. Critical self-evaluation will enable you to identify the traits in which you are strong, as well as those in which you are weak. Leadership principles can be taught, but a good leader becomes a good leader only through hard work and practice. Your success as a leader will be

judged for the most part by how well you inspire others to learn and perform, and by personal example.

NAVY ENLISTED CLASSIFICATION CODES

The Machinist's Mate rating is a source of a number of NECs (Navy Enlisted Classification Codes). NECs reflect special knowledge and skills in certain ratings. The NEC Coding System is designed to facilitate management control over enlisted skills by accurately identifying billets and personnel. It also helps ensure maximum skill utilization in distribution and detailing. The following NECs may be earned by Machinist's Mates at certain grade levels by satisfactorily completing an applicable course of instruction at a Navy Class "C" school.

AUXILIARY EQUIPMENT TECHNICIAN, MM-4245.—The skills and knowledge required for this NEC include operating and performing preventive maintenance on absorption, centrifugal and reciprocating air-conditioning plants, chilled water systems; refrigeration plants; carbon dioxide scrubbers, carbon monoxide/hydrogen burners; hydraulic systems; and high pressure air compressors; and operating submarine diesel engines.

DIESEL ENGINE (FAIRBANKS - MORSE) MAINTENANCE TECHNICIAN, MM-4246.—The holders of this NEC perform preventive, organizational and/or intermediate level maintenance on submarine diesel engines and its components including pumps, blowers, governors, injectors, cylinders, liners, pistons and connection rods, bearings, crankshaft, vertical drive assembly, lubrication oil, fuel oil, scavenging air, exhaust, starting air and cooling water systems; taking readings and making adjustments required for the proper operation and repair of the engines; and performing shipboard duties required for lube oil, trend and water analysis.

ELECTROLYTIC OXYGEN GENERATOR (MODEL 6L16) OPERATOR, MM-4252.—Personnel with this NEC operate Model 6L16 electrolytic oxygen generator.

ELECTROLYTIC OXYGEN GENERATOR (MODEL 7L16) OPERATOR/MECHANICAL TECHNICIAN, MM-4262.—Personnel with this NEC operate and maintain mechanical Model 7L16 oxygen generator; and perform organizational and intermediate level maintenance on assigned equipment.

SHIP REPAIR, OUTSIDE MACHINIST, MM-4272.—Personnel meet the requirements of MM-4272 by performing organizational and/or intermediate level maintenance on machinery at shore activity or aboard repair ships; by inspecting and disassembling damaged equipment, and requesting appropriate replacement parts; reassembling and testing repaired machinery; analyzing malfunctions to equipment and machinery, such as evaporators, generators, condensers, and fireroom equipment; testing repairs; fitting pipelines, steamlines, and waterlines; taking clearance readings and spotting-in or renewing bearings on engines, pumps, and other equipment; and rigging chain falls to lift heavy equipment.

GAS GENERATING MECHANIC, MM-4282.—The skills and knowledge required for this NEC compel the man to operate, maintain, test, inspect, assemble, disassemble, and perform organizational and/or intermediate and/or depot level maintenance on compressed gas and liquid generating equipment. The holder of MM-4282 charges reaction vessels, maintains correct temperatures for proper functioning, and makes adjustments to equipment under various climatic conditions; analyzes gas at various stages to ensure proper quality; paints gas cylinders for handling, stowage, testing, and ready identification; maintains machinery histories and other required reports.

LOW PRESSURE O2N2 PRODUCING SYSTEM MECHANIC, MM-4283.—The holders of this NEC operate, maintain, and perform organizational level and/or intermediate level maintenance on the COSMODYNE low pressure type oxygen-nitrogen producing system. The holder of MM-4283 operates and maintains Elliott centrifugal compressor with Hagan pneumatic controls; monitors material condition of turbo expander to determine replacement; operates and maintains air purifiers and supporting cryogenic equipment; tests oxygen and nitrogen for purity; maintains correct system temperatures for capacity production under various climatic conditions.

REFRIGERATION AND AIR-CONDITIONING MECHANIC, MM-4294.—Personnel with this

NEC operate, maintain, and perform organizational and/or intermediate level maintenance on refrigeration, air-conditioning, and water-cooling systems; start idle refrigeration plants and maintain proper temperatures for ice boxes and cold storage spaces; overhaul and repair equipment such as cylinder liners, piston rings, bearings and shafts, solenoid, and expansion and relief valves.

UNREP EQUIPMENT MECHANIC, MM-4295.—This NEC is assigned to personnel who operate, maintain, and perform organizational level maintenance on hydro-pneumatic and electro-hydraulic equipments and machinery associated with UNREP System; and test and repair hydraulic power supplies, circuits, motors, valves, and other components.

TRAINING FOR THE JOB

Highly trained personnel are essential to the successful functioning of the Navy. As you continue your training and become more and more proficient in job performance, you as well as the Navy benefit. In addition to enjoying the satisfaction of getting ahead in your chosen Navy career, you will be regarded with greater respect by officers and enlisted personnel, your job assignments will become more interesting and more challenging, and your pay will increase. As you advance from one rate level to the next, you increase your value to the Navy in two ways. First, you become more valuable as a specialist in your own rating, and second, you become more valuable as a person who can train others and thus make far-reaching contributions to the entire Navy.

QUALIFYING FOR THE JOB

What must you do to meet the job requirements? The requirements may change from time to time, but usually you must:

1. Have a certain amount of time in your present grade.

2. Complete the required military and rating manuals.

3. Demonstrate your ability to perform all those practical requirements applicable to the rate for which you are striving and have them checked off on the Record of Practical Factors, NAVPERS 1414/1.

4. Be recommended by your commanding officer after the petty officers and officers supervising your work have indicated that they consider you capable of performing the duties of the next higher rate.

5. Demonstrate your knowledge by passing written examinations on the occupational and military qualification standards for advancement.

Some of these general requirements may be modified in certain ways. Figure 1-1 gives a more detailed view of the requirements for advancement of active duty personnel; figure 1-2 gives this information for inactive duty personnel.

Remember that the qualifications for advancement can change. Check with your division officer or training officer to be sure that you know the most recent qualifications.

Advancement is not automatic. Even though you have met all the requirements, including passing the written examinations, you may not be able to "sew on the crow" or "add a stripe." The number of men in each rate and rating is controlled by a Navywide basis. Therefore, the number of men who may be advanced is limited by the number of vacancies that exist. When the number of men passing the examination exceeds the number of vacancies, some system must be used to determine which men may be advanced and which may not. The system used is the "final multiple" and is a combination of three types of advancement systems.

Merit rating system
Personnel testing system
Longevity, or seniority, system

The Navy's system provides credit for performance, knowledge, and seniority, and, while it cannot guarantee that any one person will be advanced, it does guarantee that all men within a particular rating will have equal advancement opportunity.

A change in promotion policy has been implemented — the Passed-But-Not-Advanced (PNA) Factor. Under this policy, effective with the August 1972 examination, a man that passed the examination, but was not advanced can gain points toward promotion in his next attempt. Up to three multiple points can be gained in a single promotion period. The points can then be accumulated over six promotion periods up to a maximum of 15. The addition of the PNA factor, with its 15 points maximum, raised the number of points possible on an examination

<table>
<tr><th>REQUIREMENTS *</th><th>E1 to E2</th><th>E2 to E3</th><th>#† E3 to E4</th><th>#E4 to E5</th><th>† E5 to E6</th><th>† E6 to E7</th><th>† E7 to E8</th><th>† E8 to E9</th></tr>
<tr><td>SERVICE</td><td>4 mos. service—or completion of</td><td>8 mos. as E-2.</td><td>6 mos. as E-3</td><td>12 mos. as E-4</td><td>24 mos. as E-5.</td><td>36 mos. as E-6. 8 years total enlisted service.</td><td rowspan="2">36 mos. as E-7. 8 of 11 years total service must be enlisted.</td><td rowspan="2">24 mos. as E-8. 10 of 13 years total service must be enlisted.</td></tr>
<tr><td>SCHOOL</td><td>Recruit Training. (C.O. may advance up to 10% of graduating class.)</td><td></td><td>Class A for PR3, DT3, PT3, AME 3, HM 3, PN 3, FTB 3, MT 3,</td><td></td><td></td><td>Class B for AGC MUC, MNC. ††</td></tr>
<tr><td>PRACTICAL FACTORS</td><td>Locally prepared check-offs.</td><td colspan="7">Record of Practical Factors, NavPers 1414/1, must be completed for E-3 and all PO advancements.</td></tr>
<tr><td>PERFORMANCE TEST</td><td></td><td></td><td colspan="4">Specified ratings must complete applicable performance tests before taking examinations.</td><td></td><td></td></tr>
<tr><td>ENLISTED PERFORMANCE EVALUATION</td><td colspan="2">As used by CO when approving advancement.</td><td colspan="6">Counts toward performance factor credit in advancement multiple.</td></tr>
<tr><td>EXAMINATIONS**</td><td>Locally prepared tests.</td><td>See below.</td><td colspan="4">Navy-wide examinations required for all PO advancements.</td><td colspan="2">Navy-wide, selection board.</td></tr>
<tr><td>RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)</td><td></td><td colspan="5">Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NavPers 10052 (current edition).</td><td colspan="2">Correspondence courses and recommended reading. See NavPers 10052 (current edition).</td></tr>
<tr><td>AUTHORIZATION</td><td colspan="2">Commanding Officer</td><td colspan="6">Naval Examining Center</td></tr>
</table>

* All advancements require commanding officer's recommendation.
† 1 year obligated service required for E-5, and E-6; 2 years for E-7, E-8, and E-9.
\# Military leadership exam required for E-4 and E-5.
** For E-2 to E-3, NAVEXAMCEN exams or locally prepared tests may be used.
†† Waived for qualified EOD personnel.

Figure 1-1.—Active duty advancement requirements.

REQUIREMENTS*	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
TOTAL TIME IN GRADE	4 mos.	8 mos.	6 mos.	12 mos.	24 mos.	36 mos. with total 8 yrs service	36 mos. with total 11 yrs service	24 mos. with total 13 yrs service
TOTAL TRAINING DUTY IN GRADE †	14 days	14 days	14 days	14 days	28 days	42 days	42 days	28 days
PERFORMANCE TESTS			Specified ratings must complete applicable performance tests before taking examination.					
DRILL PARTICIPATION	Satisfactory participation as a member of a drill unit in accordance with BUPERSINST 5400.42 series.							
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)	Record of Practical Factors, NavPers 1414/1, must be completed for all advancements.							
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	Completion of applicable course or courses must be entered in service record.							
EXAMINATION	Standard Exam		Standard Exam required for all PO advancements. Also pass Military Leadership Exam for E-4 and E-5.				Standard Exam, Selection Board.	
AUTHORIZATION	Commanding Officer		Naval Examining Center					

*Recommendation by commanding officer required for all advancements.
† Active duty periods may be substituted for training duty.

Figure 1-2.—Inactive duty advancement requirements.

multiple from 185 to 200. This gives the examinee added incentive to keep trying for promotion in spite of repeated failure to gain a stripe because of quota limitations.

The following factors are considered in computing the final multiple.

Factor	Maximum Points	Weight
Examination Score	80	40%
Performance (Average of marks received)	50	25%
Total Active Service (1 per yr)	20	10%
Time in Present Grade (2 per yr)	20	10%
Medals and Awards	15	7.5%
PNA (Maximum 3 per exam cycle)	15	7.5%
	200	100%

All of the above information (except the examination score and the PNA factor) is submitted to the Naval Examining Center with your examination answer sheet. After grading, the examination scores, for those passing, and the PNA points (additional points awarded to those who previously passed the examination but were not advanced) are added to the other factors to arrive at the final multiple. A precedence list, which is based on final multiples, is then prepared for each pay grade within each rating. Advancement authorizations are then issued, beginning at the top of the list, for the number of men needed to fill the existing vacancies.

MEETING JOB REQUIREMENTS

What must you do to prepare for your job at the next higher level? You must study the qualifications for advancement, work on the practical factors, study the required rate training manuals, and study other material that is required for advancement. This will require that you be (1) familiar with the Quals Manual, (2) complete the Record of Practical Factors, (3) use the Bibliography for Advancement Study, NAVTRA 10052, and (4) complete applicable rate training manuals. The following sections describe each of these and give you some practical suggestions on how to use them.

Quals Manual

The Manual of Qualifications for Advancement, NAVPERS 18068-C, gives the minimum requirements (qualification standards) for advancement to each pay grade within each rating. This manual is usually called the "Quals Manual" and the qualifications themselves are often called "quals." The qualification standards are of two general types: (1) military qualification standards and (2) occupational qualification standards.

MILITARY QUALIFICATION STANDARDS are requirements that apply to any one particular rating. Military requirements for advancement to third class and second class petty officer rates deal with military conduct and readiness, naval organization, military justice, security, watch standing, and other subjects which are required of petty officers in all ratings.

OCCUPATIONAL QUALIFICATION STANDARDS are requirements that are directly related to the work of each rating.

Both the military requirements and the occupational qualification standards are divided into subject matter groups; then, within each subject matter group, they are divided into PRACTICAL FACTORS and KNOWLEDGE FACTORS. Practical factors relate to jobs you must be able to DO. Knowledge factors specify subject matter areas you must KNOW to perform assigned duties.

In most subject matter areas, you will find both practical factor and knowledge factor qualifications. In some subject matter areas, you may find only one or the other. It is important to remember that there are some knowledge aspects to all practical factors, and some practical aspects to most knowledge factors. Therefore, even if the Quals Manual indicates that there are no knowledge factors for a given subject matter area, you may still expect to find examination questions dealing with the knowledge aspects of the practical factors listed in that subject matter area.

You are required to pass a Navywide military/leadership examination for E-4 or E-5, as appropriate, before you take the occupational examinations. The military/leadership examinations are administered on a schedule determined by your commanding officer. Candidates

are required to pass the applicable military/leadership examination only once. Each of these examinations consists of 100 questions based on information contained in Military Requirements for Petty Officers 3 & 2, NAVPERS 10056 (revised) and other publications listed in Bibliography for Advancement Study, NAVTRA 10052.

The Navywide occupational examinations for pay grades E-4 and E-5 will contain 150 questions related to occupational areas of your rating. If you are working for advancement to second class, remember that you may be examined on third class qualifications as well as on second class qualifications.

The Quals Manual is kept current by means of changes. The occupational qualifications for your rating which are covered in this training manual were current at the time the manual was printed. By the time you study this manual, however, the quals for your rating may have been changed. Never trust any set of quals until you have checked it against an UP-TO-DATE Quals Manual.

Record of Practical Factors

Before you can take the servicewide examination for advancement, there must be an entry in your service record to show that you have qualified in the practical factors of both the military and the occupational qualifications. The Record of Practical Factors, mentioned earlier, is used to keep a record of your practical factor qualifications. This form is available for each rating. The form lists all practical factors, both military and occupational. As you demonstrate your ability to perform each practical factor, appropriate entries are made in the DATE and INITIALS columns.

Changes are made periodically to the Manual of Qualifications for Advancement, and revised forms of NAVPERS 1414/1 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement.

Until completed, the NAVPERS 1414/1 is usually held by your division officer; after completion, it is forwarded to the personnel office for insertion in your service record. If you are transferred before qualifying in all practical factors, the incomplete form should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form actually is inserted in your service record before you are transferred. If the form is not in your service record, you may be required to start all over again and requalify in the practical factors which have already been checked off.

NAVTRA 10052

The Bibliography for Advancement Study, NAVTRA 10052 (revised), is a very important publication for any enlisted person preparing for advancement. This bibliography lists required and recommended rate training manuals and other reference material to be used by personnel working for advancement.

NAVTRA 10052 is revised and issued once each year by the Naval Training Command. Each revised edition is identified by a letter following the number. When using this publication, be SURE that you have the most recent edition.

If extensive changes in qualifications occur in any rating between the annual revisions of NAVTRA 10052, a supplementary list of study material may be issued in the form of a NAVTRA Notice. When you are preparing for advancement, check to see whether changes have been made in the qualifications for your rating. If changes have been made, see if a NAVTRA Notice has been issued to supplement NAVTRA 10052 for your rating.

In using NAVTRA 10052, you will notice that some rate training manuals are marked with an asterisk(*). Any manual marked in this way is MANDATORY—that is, it must be completed at the indicated rate level before you can be eligible to take the servicewide examination for advancement. Each mandatory manual may be completed by (1) passing the appropriate enlisted correspondence course that is based on the mandatory training manual; (2) passing locally prepared tests based on the information given in the training manual; or (3) in some cases, successfully completing an appropriate Navy school.

Do not overlook the section of NAVTRA 10052 which lists the required and recommended references relating to the military qualification standards for advancement. Personnel of ALL ratings must complete the mandatory military

requirements training manual for the appropriate rate level before they can be eligible to advance.

The references in NAVTRA 10052 which are recommended but not mandatory should also be studied carefully. ALL references listed in NAVTRA 10052 may be used as source material for the written examinations at the appropriate rate levels. In addition, references listed in the rate training manual may also be used as source material for preparing examination questions.

Rate Training Manuals

There are two general types of rate training manuals. RATING manuals (such as this one) are prepared for most enlisted ratings. A rate training manual gives information that is directly related to the occupational qualifications of ONE rating. SUBJECT MATTER manuals or BASIC manuals give information that applies to more than one rating.

Rate training manuals are revised from time to time to keep them up to date technically. The revision of a rate training manual is identified by a letter following the NAVTRA number. You can tell whether any particular copy of a training manual is the latest edition by checking the NAVTRA number and the letter following this number in the most recent edition of <u>List of Training Manuals and Correspondence Courses</u>, NAVTRA 10061. (NAVTRA 10061 is actually a catalog that lists all current training manuals and correspondence courses; you will find this catalog useful in planning your study program.)

Each time a rate training manual is revised, it is brought into conformance with the official publications and directives on which it is based; but during the life of any edition, discrepancies between the manual and the official sources are almost certain to arise because of changes to the latter which are issued in the interim. In the performance of your duties, you should always refer to the appropriate official publication or directive. If the official source is listed in NAVTRA 10052, the Naval Examination Center uses it as a source of questions in preparing the fleetwide examinations for advancement. In case of discrepancy between any publications listed in NAVTRA 10052 for a given rate, the Examining Center will use the most recent material.

Rate training manuals are designed to help you prepare for advancement. The following suggestions may help you to make the best use of this manual and other Navy Training publications when you are preparing for advancement.

1. Study the military and the occupational qualifications for your rating before you study the training manual, and refer to the quals frequently as you study. Remember, you are studying the manual primarily in order to meet these quals.

2. Set up a regular study plan. It will probably be easier for you to stick to a schedule if you can plan to study at the same time each day. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the manual intensively, become familiar with the entire manual. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the manual without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training manual in more detail to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a pretty clear picture of the scope and content of the manual. As you look through the manual in this way, ask yourself such questions as:

- What do I need to learn about this?
- What do I already know about this?
- How is this information related to information given in other chapters?
- How is this information related to the qualifications for advancement?

5. When you have a general idea of what is in the training manual and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. The amount of material that you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit—chapter, section, or subsection—write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least write down the most important ideas.

7. As you study, relate the information in the training manual to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without looking at the training manual, write down the main ideas that you have gotten from studying this unit. Don't just quote the manual. If you can't give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use enlisted correspondence courses whenever you can. The correspondence courses are based on rate training manuals or on other appropriate texts. As mentioned before, completion of a mandatory rate training manual can be accomplished by passing an enlisted correspondence course based on the rate training manual. You will probably find it helpful to take other correspondence courses as well as those based on mandatory manuals. Taking a correspondence course helps you to master the information given in the training manual, and also helps you see how much you have learned.

10. Think of your future as you study rate training manuals. You are working for advancement to third class or second class right now, but some day you will be working toward higher rates. Anything extra that you can learn now will help you both now and later.

SOURCES OF INFORMATION

One of the most useful things you can learn about a subject is how to find out more about it. No single publications can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the military qualification requirements for advancement and the occupational qualification requirements of your rating.

Some of the publications described here are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance; it is likely to be a waste of time, and may even be seriously misleading.

NAVAL TRAINING (NAVTRA) PUBLICATIONS

Effective 15 January 1972, the Naval Training Support Command and its field activities came directly under the command of the Chief of Naval Training instead of the Chief of Naval Personnel. Training materials published by the Naval Training Command after the above date are designated as NAVTRA in lieu of NAVPERS; the number remains as originally assigned for most publications. The designators of publications printed prior to the above date will be changed as each publication is revised.

Some of the publications that you will need to study or refer to as you prepare for advancement have already been discussed earlier in this chapter. Some additional publications that you may find useful are Tools and Their Uses, NAVPERS 10085-B, Blueprint Reading and Sketching, NAVPERS 10077-C, Fireman, NAVPERS 10520-D, Basic Machines, NAVPERS 10024-A, and Fluid Power, NAVPERS 16193-B.

NAVSHIPS PUBLICATIONS

A number of publications issued by the Naval Ship Systems Command (NAVSHIPS) will be of interest to you. While you do not need to know everything that is given in the publications mentioned here, you should have a general idea of where to find information in NAVSHIPS publications.

The Naval Ships Technical Manual is the basic doctrine publication of NAVSHIPS. To allow the ship to distribute copies to the working spaces where information is required, chapters are now issued as separate paper-bound volumes. Chapters are kept up-to-date by means of yearly revisions or less frequently for those chapters where yearly revisions are not necessary. In chapters where intra-year changes are required, either an intra-year edition or a NAVSHIPS Notice will be distributed as a temporary supplement for use pending issue of the new edition of the chapter.

Chapters in Naval Ships Technical Manual of particular importance to the Machinist's Mate are referenced in this training manual. For a

list of all chapters in the manual, see appendix A, chapter 9000.

The Naval Ship Systems Command Technical News is a monthly publication which contains interesting and useful articles on all aspects of shipboard engineering. This magazine is particularly useful because it presents information which supplements and clarifies information contained in the Naval Ships Technical Manual and because it presents information on new developments.

The manufacturer's technical manuals that are furnished with most machinery units and many items of equipment are valuable sources of information on operation, maintenance, and repair. The manufacturer's technical manuals that deal with NAVSHIPS machinery and equipment are usually given NAVSHIPS numbers.

BLUEPRINTS AND SHIP'S PLAN INDEX

As a Machinist's Mate, you are required to use mechanical drawings and handbooks to obtain data when repairing machinery. You must also be able to read and interpret blueprints, a principal source of information required for repair work, and you must have a knowledge of the Ship's Plan Index. Information on how to read and interpret blueprints is available in Blueprint Reading and Sketching, NAVPERS 10077-C. Supplementary information is provided in the following paragraphs on the filing of blueprints.

All ships use a standard system of filing plans by their assigned code number, although the number and type of plans carried will be different on different ships. The number assigned to a plan for identification and filing purposes is composed of several groups. There are two types of numbering systems in use: (1) the older system, referred to as the S-group numbering system, and (2) the new consolidated index numbering system. For example, in NAVSHIPS drawing number CA-139-S5101-525802, which is an S-group numbered drawing, or LST 1173-206-2465214A, which uses the consolidated index numbering system, the group CA 139 and LST 1173 is the class ship designation or the class of ships for which the plan applies. The next group is S5101, which is the subject matter group or material file number, or 206, which is the consolidated index number. In this example, the S-group number identifies a plan on the automatic combustion controls of a boiler. The index number 206 identifies the plan on the same subject as the S-group number. The S-group numbers and the consolidated index numbers are cross-referenced in NAVSHIPS Consolidated Index of Materials and Services Related to Construction and Conversion.

In either system, the last group of numbers is the individual plan number or serial number. Except for multisheet plans, no two plans will bear the same serial number. If an alteration or change has been made, the accompanying plan will have an alteration number or a revision letter. If the drawing is under the S-group numbering system, it will have an alteration number such as CA 139-S5101-525802 Alt. 2; the Alt 2 is the alteration number. If all alterations have been completed, the plan Alt 2 is kept on file. If the plan is under the consolidated index numbering system, it will have a revision letter. With this system, the original plan is always designated as REV A. A plan number of LST 1173-206-2465214C would indicate that the plan is the second revision of the original plan. Care must be taken to see that you have an up-to-date plan and not one that is obsolete. This can be done by checking the ALT number or the REV letter.

Upon completion of a Navy ship, the shipbuilder furnishes the ship with copies of all plans considered necessary for operating and maintaining the ship (onboard plans), and a Ship Plan Index (SPI). The SPI lists all plans applicable to the ship concerned except plans for certain miscellaneous items covered by standard or type plans.

On most ships, plans are filed in the engineering log room. Aboard tenders and repair ships, they may be filed in the technical library or the microfilm library. The plans are filed in cabinets in numerical sequence according to the three-digit or "S" group number and the file number. When a later revision of a plan is received, the plan with the previous revision is removed from the file and destroyed, and the current plan filed in its place.

SPECIFICATIONS AND STANDARDS

Blueprints contain all the information about an object or part which can be presented graphically (that is, in drawing). A considerable amount of information can be presented this way, but there is more information required by supervisors, contractors, manufacturers, and craftsmen, which is not adaptable to the graphic form of presentation. Information of this type

is generally given on the drawings as notes or as a set of specifications attached to be drawings.

A SPECIFICATION is a statement or document containing a description or enumeration of particulars, as the terms of a contract, or details of an object or objects not shown on a blueprint or drawing.

Specifications (specs) describe items so that they may be procured, assembled, and maintained to function in accordance with the performance requirements; furnish sufficient information to permit determination of conformance to the description; and furnish the above in sufficient completeness for accomplishment without the need of research, development, design engineering, or help from the preparing organization.

Federal specifications cover the characteristics of material and supplies used jointly by the Navy and other Government departments.

All Federal specifications used by the Navy Department as purchase specifications are listed in the Department of Defense Index of Specifications and Standards.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. Training films are listed in the United States Navy Film Catalog, NAVAIR 10-1-777. Copies may be ordered in accordance with the Navy Stock List of Forms and Publications, NAVSUP 2002. Supplements to the Film Catalog are issued as appropriate.

When selecting a film, note its date of issue listed in the Film Catalog. As you know, procedures sometimes change rapidly. Thus some films become obsolete rapidly. If a film is obsolete only in part, it may sometimes be shown effectively if before or during its showing you carefully point out to trainees the procedures that have changed.

CHAPTER 2

GENERAL ENGINEERING SAFETY

The Secretary of the Navy, in establishing a Department of the Navy Safety Program, stressed "Safety is an inherent responsibility of command..." He further outlined that "Assignment of safety responsibility at all echelons of command is a basic requirement." This means responsibility right down through second and third class petty officers. Most accidents which occur in noncombat operations can be prevented if all personnel cooperate in eliminating unsafe conditions and acts.

To assist shipboard personnel in carrying out their responsibilities concerning safety, the Chief of Naval Operations has issued instructions on the subject. In addition, safety information is issued periodically in various publications, pamphlets, and directives by commands, bureaus, and offices of the Navy Department. Also, the Naval Safety Center, Norfolk, Virginia, a portion of whose mission is to monitor safety in the fleet, obtains accident data from completed Accident/Near Accident Reports (3040 forms) and Accidental Injury/Death Reports (5100 forms) and from Safetygrams, which are submitted informally by ships. Publications issued by the Center of particular interest to forces afloat include FATHOM and Ships Safety Bulletin.

The 3-M (Maintenance Material Management) SYSTEM is potentially the most valuable contribution to shipboard safety yet devised. It is easily capable of supporting a major portion of an overall shipboard safety program. As a management information system the 3-M System is the primary vehicle by which management control; policy direction, and technical supervision are progressively exercised from one echelon to another. A flow of accomplishments and things to be accomplished can be developed between interested managers at all levels. The 3-M is divided into two subsystems: PMS (Planned Maintenance System) and MDCS (Maintenance Data Collection System). Both are tools in various stages of growth and transition. Both are solid bases for a highly efficient shipboard accident prevention plan.

This chapter includes some of the areas in which you should exercise above average caution. It further provides some facts so that you can teach safety accurately and effectively. Finally, it lists some of the approved methods of action so that you will be able to rehearse your actions and be ready in the event of a casualty.

Detailed Instructions and procedures pertaining to safety are contained in general and specific manuals such as Naval Ships Technical Manual (NSTM); chapter 9000, gives an index of NSTM chapters which will be important to you. The safety precautions discussed in this chapter are not intended to replace those in various manuals. Safety precautions related to specific machinery are included at appropriate points throughout this training manual.

SAFETY RULES

All individuals have the responsibility to understand and observe safety standards and regulations which are established for the prevention of injury to themselves and other persons and damage to property and equipment. As a supervisor, you have the responsibility of setting a good example; you cannot ignore safety regulations and expect others to follow them.

To help your men perform their work as safely as possible, you must OBEY THE TEN COMMANDMENTS OF SAFETY:

1. LEARN the safe way to do your job before you start.
2. THINK safety, and ACT safety at all times.
3. OBEY safety rules and regulations — they are for your protection.
4. WEAR proper clothing and protective equipment.
5. CONDUCT yourself properly at all times — horseplay is prohibited.
6. OPERATE only the equipment you are authorized to use.

7. INSPECT tools and equipment for safe condition before starting work.
8. ADVISE your superior promptly of any unsafe condition or practice.
9. REPORT any injury immediately to your superior.
10. SUPPORT your safety program and take an active part in safety meetings.

ACCIDENTS

Accidents don't just happen. Accidents are preventable, and as a petty officer on board ship and ashore, it is your job to prevent them. All accidents have a "cause," and it is a well established fact that 75 percent of the varied causes is "deviation from one or more safety precautions." It is also your job as a petty officer to know and be able to perform the proper action when an accident does occur.

Accidents are always unexpected by the persons to whom they occur. If this were not so, accidents would not happen. A person who expects an accident to occur will do something to avoid it. For example, if a sailor expects a hatch to come unlatched and fall on him, he will see to it that the toggle pin secures the latch before he descends the ladder into the compartment below.

There are two practical implications about the idea that accidents occur because they are unexpected. First, it pays to train people to know about the unexpected. The more sailors know about what can and might happen, the more likely will they act so that such things do not happen. For example, if a Machinist's Mate understands that someone may open an air valve while he is working on an air compressor line, he will be more likely to protect himself by making sure that all valves that could admit air to that section of piping are wired and tagged shut prior to commencing work.

The second implication is that it pays to convince people that the unexpected will occur sooner or later unless they take appropriate precautions. The more sailors are convinced that the unexpected will occur unless they take definite steps to guard against it, the more likely they will apply those precautions. For example, a sailor who is convinced that, sooner or later, he will get a foreign object in his eye unless he wears goggles is very unlikely to use a power grindstone without wearing goggles. Being convinced about what will occur prompts him to protect himself.

Accidents usually involve some type of unexpected contact between a person or ship and some object, substance or exposure in the environment. There are exceptions. One exception is the over-exertion accident in which a person injures himself by putting excessive strain on some part of his body. An example is a man who injures his back as a result of lifting a heavy object while in an awkward position.

The point that accidents are contacts is worth stressing because it focuses attention more specifically on what we are trying to prevent. We are trying to prevent certain types of unexpected contacts. Once you get into the habit of thinking of accidents as contacts, you will recognize more potential accidents in the work you supervise. Being contact minded will enable you to do a better job of observing for unsafe practices, inspecting for unsafe conditions, and analyzing jobs for safer methods. Think of accidents as unexpected contacts.

BASIC TYPES OF UNSAFE ACTS

There are many variations of the basic types of unsafe acts. Once you know the basic unsafe acts and understand why they are unsafe acts, you should have no trouble recognizing the many variations. Basic unsafe acts that you should emphasize in your safety training and be alert for generally are:

Operating or Using Equipment Without Authority.—Sometimes sailors will use equipment or operate machines, valves, and switches without authorization. Unauthorized persons usually lack the knowledge or skill to operate equipment safely.

Failure to Secure Against Unexpected Movement.—Any equipment or materials capable of unexpected start-up or unexpected movement like slipping, sliding, rolling, falling, or drifting must be made secure against such possibilities. Specific examples are failure to tag out or disconnect the controller of an electric pump before making repairs or adjustments and failure to install battens to prevent stores from shifting in a store room.

Operating or Working at an Unsafe Speed.—Some men will try to get things done too quickly. They will operate a machine or vehicle at an excessive speed. Or, they will take short cuts on a job to hurry it along. Rushing a job by running, throwing, improvising, or taking short

cuts invariably increases the risk of an accident.

Removing or Making Safety Devices Inoperative.—Equipment guards and other safety devices are never installed unless a serious hazard requires their installation. It is a serious unsafe practice to render such devices inoperative by removing or tampering with them. Examples include disconnecting speed limiting governors to gain speed, gagging pressure relief valves to stop leaks, making limit switches inoperative to gain more room for movement and removing machinery guards to make adjustments or lubrication easier.

Using Defective Tools or Equipment.—Most tools and equipment develop defective, unsafe conditions in time through normal wear, and sometimes because of misuse or abuse. When they do, they should be repaired or replaced. Continued use of equipment in a defective condition invites accidents. Examples of this unsafe practice include using tools with loose handles, chisels with mushroomed heads, and portable electric tools with frayed cable or not having a suitable ground.

Using Tools or Equipment Unsafely.—Sailors will often use sound tools and equipment in an unsafe way. Frequently the tool or equipment is used for a purpose other than for which it was designed, e. g., a screw driver may be used as a chisel or punch. Just as frequently the tool or equipment is used for the right purpose but in a wrong way, e. g., hammering with the side of a hammer or exerting abrupt force on a wrench.

Taking an Unsafe Position or Posture.—Many accidents occur because men put themselves in hazardous positions relative to the things around them. Examples included working directly below where overhaul work is being done, walking under crane lifts, and standing too close to a tool swinging shipmate. An unsafe posture concerns how a man positions his body, not where he positions it. A typical example of unsafe posture is lifting a heavy object with legs straight and back arched down to the load.

Servicing Moving, Energized or Otherwise Hazardous Equipment.—Repair or service work should never be undertaken when the equipment is either moving, energized, or pressurized. Failure to shut down, de-energize, or depressurize equipment before repairing, cleaning, lubricating, adjusting, or inspecting can be fatal. Whenever such equipment is worked on, appropriate securing and light off procedures should be followed.

Engaging in Horseplay.—Many accidents with serious injury consequences are caused by horseplay of one kind or another; such actions must be recognized as a basic type of unsafe act. Rough housing, throwing objects, water splashing and similar hazardous antics should not be tolerated by any petty officer.

Failing to Wear Personal Protective Equipment.—When personal protective equipment is prescribed and issued, it is because past accident experience has made the decision. Failure to wear hard hats, safety goggles, face shields, and protective clothing is an open invitation to serious injury.

The way to prevent unsafe practices is to eliminate their causes. That means we must eliminate as much as possible the lack of knowledge about hazards and safe job procedures, inadequate job skills, lack of incentive to work safely, motivations that conflict with working safely, physical and mental conditions of unfitness to work safely, and other personal factor causes of unsafe practices. The way to eliminate unsafe conditions is to correct the condition plus the causes of the condition.

GENERAL HOUSEKEEPING STANDARDS

Good housekeeping goes hand in hand with safety and efficiency. It is a combination of orderliness and cleanliness. To promote orderliness, see to it that all items (1) have an assigned place for storage, (2) are kept in their assigned places when not in use, and (3) are stowed in their assigned places in a ready-for-sea condition.

To promote cleanliness, see to it that the sources of avoidable uncleanliness are corrected and the unavoidable conditions are regularly cleaned up. Establish housekeeping standards for your own area of supervision and assign individual responsibility for complying with your standards.

PRECAUTIONS AND PROCEDURES

In all cases of accident, every endeavor must be made to localize the damage. The compartment involved must be isolated to prevent damage from

spreading to other compartments and interfering with proper attendance on other machinery in use. All men on duty must remain at their proper stations and give strict attention to the machinery in operation. When considerable leaks of steam occur in a space, the upper part of the compartment generally becomes filled with steam; men must not be allowed to go up the ladders at such times because of great danger of their being seriously injured or overcome by inhaling steam. The best avenue of escape, if it becomes necessary to abandon the compartment, is to another compartment on a lower level. To assist in escaping, a knowledge of the location of equipment such as the engine, turbines, pumps, blowers, and their emergency stop controls and switches is also essential. In case of oil fires in bilges, close master valve and stop oil pump. Shut down or keep blowers running when oil fires occur, depending upon circumstances whether it is better to risk fanning the flames, or to aid personnel in escaping. Under some circumstances, it may be necessary to energize the CO_2 flooding system. In such a case, make absolutely sure the compartment is free of personnel.

Casualties resulting in personal injury, no matter how minor, must be reported to the Engineering Officer of the Watch when underway, and to the Duty Engineering Officer when in port. This action is required so that the appropriate entry may be entered in the Engineering Log, NAVPERS 117.

HANDLING MATERIAL

When working on shipboard machinery, there are several things you can do to prevent accidents. Chain hoists are usually provided to lift heavy objects. However, if a heavy object must be removed by hand, there is a proper way of doing it. The lifter should stand close to the load, with feet solidly placed and slightly apart. With knees bent, he should grasp the object firmly, and then lift by straightening the legs, keeping the back as vertical as possible. Never stand on a slippery deck to lift a heavy object, nor reach for it.

Materials should never be thrown from elevated places to the deck. Suitable lowering equipment should always be used.

Lifting or lowering operations being performed by several persons should be done on signal from one person, and then only when all personnel are in the clear.

Never overload a chain hoist, block and tackle, crane or any other lifting device. Defective or broken straps should never be used.

Before any material is handled, it should be examined and personnel should be protected against sharp edges, protruding points, or other factors likely to cause accidents.

Before opening a fitting or piece of equipment, valves which permit entrance of steam, water, air, oil, etc., into the fitting of equipment should be closed, tagged, and secured by locking or wiring in order to prevent accidental opening.

Keep work areas clear of stray gear such as tools, fire hazards, and oil.

Warn others away from any known unsafe condition.

WORKING WITH HANDTOOLS

For your safety, certain precautions should be taken when working with handtools. Normally, there should be no problems when working with these tools, but there are certain conditions under which they may constitute a danger to you. One source of danger that often is neglected or ignored is the use of handtools which are no longer considered serviceable. Tools having plastic or wooden handles that are cracked, chipped, splintered, or broken may result in injuries to personnel from cuts, bruises, particles striking the eye, and the like. Such tools should be condemned, replaced, or, if at all possible, repaired, before they cause accidents.

USING POWER TOOLS

To protect yourself and others working adjacent to you, use special precautions when using a power drill and a power grinder. In the first place, do not attempt to use these tools until you have had adequate instruction in their use and you have been authorized to use them. Experimentation with power tools can be dangerous to you and result in damage to the tools. If a power drill slips, you can easily injure a finger or a hand. Always use goggles or a face shield when buffing or grinding, or when there is danger of flying particles. There is no exception to this rule.

Do not use electrical equipment or machines with frayed or otherwise deteriorated insulation. Electrically driven portable machinery and fixed electrical equipment must have the frame grounded.

Aboard ship, electrically driven portable handtools may not be operated unless they are equipped with ground wire connections between

their metal housings and the steel structure of the ship. There is no exception to this rule. These tools must be equipped with an approved type of grounding plug. You must inspect the attached cable and plug of a tool before you use it, to make certain that the insulation and contacts are in good condition. Tears, chafing, exposed insulated conductors, and damaged plugs are sufficient reasons for replacement. The tools must be inspected and tested periodically (usually weekly) by a qualified Electrician's Mate to ensure that they are properly grounded and in safe operating condition electrically. Any electrically powered handtools which have not been thus inspected by an Electrician's Mate must be considered unsafe for use.

Get a copy of TOOLS AND THEIR USES, NAVPERS 10085-B and study it carefully to learn how to use power tools safely.

USING PERSONAL EQUIPMENT

Personal radios, television sets, record players, and wire or tape recorders having metal cases or metal back or bottom are a safety hazard in many cases. In much of such equipment the chassis forms a part of the circuit and the exposed metal parts are energized, thereby creating the danger of shock to personnel touching them. Moreover, grounding these metal parts to the ship's structure would place a ground on the 115-volt lighting system contrary to the safety instructions.

In general, the molded housing on an electric shaver is a nonconducting plastic material, and the cutting blades are isolated from any contact with the electrical components within the shaver. For this reason, 3-prong grounding plugs are not required on electric shavers. For safe use aboard ship, your electric shaver should have a completely insulated housing and isolated cutting blades, and the housing and cord must be free of cracks. If in doubt whether your electric shaver complies, have it checked by the electric shop. If your electric shaver falls in a wash bowl of water, let it go. Do not touch it without first unplugging the cord from its receptacle connector. Do not try to energize it. Take it to the electric shop for a safety check first.

Personally owned or non-Navy standard electric lights, fans, and tools are not authorized. They are generally a shock hazard because of inferior insulation, leakage currents, and flimsy structure. Periodic inspections should be made to eliminate them from the ship. Adequate numbers and types of Navy lights, fans, and tools are available to meet all needs.

Personally owned hobby equipment such as handheld, motor-driven carving tools are frequently found to be of flimsy construction and unsafe for use aboard ship. Such equipment may be retained aboard ship subject to the following precautions:

- Prior to permitting use of portable, electrically operated hobby devices aboard ship, they should be inspected and tested by the Electrician's Mate. Equipments which pass this inspection should be tagged as safe, giving date of inspection. This equipment should be frequently reinspected, at least once each 6 months.
- At any time that the hobby tool is damaged or is obviously defective, that is, if molded housing, cords, or plugs contain cracks or breaks or if the cord insulation breaks when sharply bent, the tool must not be used until repaired and reinspected by the Electrician's Mate. No personal electrical equipment, such as radios, television sets, record players, wire or tape recorders, or other personal appliances as listed above, shall be used aboard ship without the Engineering Officer's Tag of Approval. Periodic inspection should be made to enforce this vital safety regulation.

PREVENTING OIL FIRES

An oil fire may be caused by the ignition of oil or oil vapor in any place where oil is allowed to spray when under pressure or is allowed to collect by leakage of spillage from the system. While specification requirements for Navy Special fuels (flash point 150° F), JP-5 (flash point 140° F), and diesel fuel (flash point 140° F), are designed to make shipboard storage and handling as safe as possible, if the flash point is exceeded, an explosive mixture with air may result. Fuel oils of lower viscosity characteristics than those prescribed for Navy Special Fuel Oil are used in the naval service but flash point must be 140° F minimum. Such fuels are either distillates or blends of residual and cutting stocks. The distillate fuels contain no residual component. The blended fuels, depending upon their viscosities, may require little or no preheat for either pumping or burning. Distillate fuels should be pumped and burned without preheating.

All fuels and lubricating oils are extremely dangerous if atomized (sprayed) through a leak

in a flange or gasket. If the spray strikes a hot surface, fire and possibly an explosion will result. Be sure you know the fuel and oil piping systems in your space and ensure that all flange safety shields are installed.

The following precautions must be taken:

1. DO NOT ALLOW OIL TO ACCUMULATE ANY PLACE. Particular care must be taken to guard against this accumulation in drip pans, under pumps, in bilges, or on the deck plates.
2. Should leakage from lubricating oil systems occur at any time, immediate action must be taken to repair the leak or, in case of a large leak, to stop the oil pumps, in accordance with low lube oil pressure casualty procedures as described in the ship's Casualty Control Book.
3. Any oil spilled must be wiped up at once.
4. Electrical apparatus shall be inspected frequently and any condition likely to cause sparking, corrected before again being used.
5. Have Oil Pollution Act posted by fire and bilge pump.
6. Don't pump bilges at night.
7. In port have man stationed topside to observe discharge.
8. Have hull valves locked and precautions posted by same.
9. Have permission from Duty Engineering Officer prior to pumping bilges.

WORKING ALOFT

When radio or radar antennas are energized by transmitters, workmen must not go aloft unless advance tests show positively that no danger exists. A casualty can occur from even a small spark drawn from a charged piece of metal or rigging. Although the spark itself may be harmless, the "surprise" may cause the man to let go his grasp involuntarily. There is also shock hazard if nearby antennas are energized, such as those on stations ashore or aboard a ship moored alongside or across a pier.

Danger also exists when radar or other rotating antennas might cause men working aloft to fall by knocking them from their perch.

When you work on a stack, draw and wear the recommended oxygen breathing apparatus. Among other toxic substances, stack gas contains carbon monoxide. Carbon monoxide is too unstable to build up to a high concentration in the open, but prolonged exposure to even small quantities is dangerous.

Observe these safety precautions when you are going aloft:

1. You must have permission of the Communications Watch Officer (CWO) and OOD.
2. You must have the assistance of another man along with a ship's Boatswain's Mate qualified in rigging.
3. Wear a safety harness. To be of any benefit, the harness must be fastened securely as soon as you reach the place where you will work. Some men have complained on occasion that a harness is clumsy and interferes with movement. It is true the job may take a few minutes longer, but it is also true that a fall from the vicinity of a stack is usually fatal.
4. Do not attempt to climb loaded with tools. Keep both hands free for climbing. Tools can be raised to you by your assistant below. Tools should be secured with preventer lines to avoid dropping them on your shipmate.
5. Ensure yourself of good footing and grasp at all times.
6. Remember the nautical expression of old seafarers: HOLD FAST.
7. Ensure that the boiler safety valves are not being set by checking with your leading petty officer.

WORKING IN CLOSED SPACES

SINCE you normally think of breathing as an automatic body function, you seldom worry about the air being safe (or unsafe) to breathe. But on naval ships this is a very real problem which has cost many lives. This is especially true in spaces that are not well ventilated or which have been closed for appreciable lengths of time. Unventilated storerooms, blisters, double bottoms, tanks, cofferdams, pontoons, voids and cold boilers are typical "iron coffins."

The air you breathe is composed of several different gases. Approximately 20 percent of the air content is oxygen under NORMAL conditions. If for any reason this percentage is reduced much below 16 percent you cannot survive. Fire, rusting, the drying of paint and the decomposition of organic material can all contribute to oxygen deficiency. If you step into a closed compartment and there is insuffcient oxygen in the air to support life, the results will be painfully swift. You will be immediately weakened. Your body may not respond to even the most desperate efforts to escape. If the oxygen content is particularly low, you may have time for only a few futile gasps before losing consciousness. Death may be only

a breath away in an oxygen deficient atmosphere. But BEWARE even if the air does contain enough oxygen, it may also contain concentrations of other gases which are flammable, toxic or both. Flammable or toxic gases and vapors may be just as deadly as the lack of oxygen.

The first question which comes to mind is, "What precautions should I take before entering a closed or poorly ventilated compartment?" Aboard a naval ship, no person may enter any closed compartment or poorly ventilated space until the gas free engineer or his authorized representative has declared that the applicable safety and entry precautions have been complied with and that the danger of poisoning or suffocation or ignition of flammable materials or gases has been eliminated or reduced to the lowest practicable minimum.

ELECTRICAL SAFETY

Even though the care and maintenance of electrical equipment is the responsibility of an EM, you as an MM should be familiar with the precautions to be observed when you are working around electrical equipment. Safety precautions must always be observed by any person working around electrical circuits and equipment, so that injury caused by contact with electrically charged objects may be avoided.

Electrical shock due to contact with an energized circuit can cause serious injury. Even low voltage circuits (115 volts and below) can cause death upon contact, especially when current passes through the chest.

Shipboard conditions are particularly conducive to severe shocks because, (1) the body is likely to be in contact with the ships metal structure and (2) the body resistance to electricity may be low because of perspiration or damp clothing. Extra care is therefore needed when working in the vicinity of electrical circuit on board ship.

Extreme care should be exercised to prevent short circuits. Short circuits may be caused by accidentally placing or dropping a metal tool, flashlight case, or some other conducting object on an energized line. The arc or the fire that may result can cause extensive damage to equipment and personnel. Safety precautions are posted in the vicinity of electrical equipment. If these simple rules are observed, injury or accident will seldom occur. When working around electrical equipment keep in mind that electricity strikes without warning, that hurrying reduces caution and invites accidents, and that every electrical circuit is a potential source of danger.

Rescue of Victims

Even when safety precautions are observed, accidents may occur. You should be familiar, therefore, with the procedures to be followed when rescue from electrical contact is necessary and injury from electricity has been received. Rescuing a person who is in contact with an electrically charged object is likely to be a difficult and dangerous job.

Extreme caution must be used, otherwise you may be electrocuted yourself. You must not touch the victim's body, the charged object or any other object which may be conducting electricty.

> **WARNING**
>
> DO NOT attempt to administer first aid or come in physical contact with an electric shock victim before the victim has been removed from the live conductor.

When attempting to administer first aid to an electric shock victim, proceed as follows:

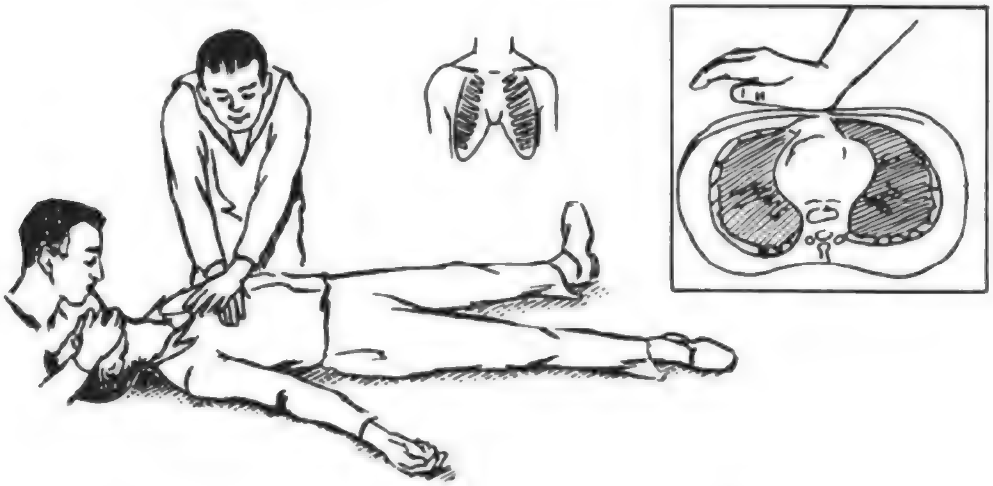
1. Shut off the high voltage.
2. If the high voltage cannot be deactivated, remove the victim immediately, observing the following precautions:
   a. Protect yourself with dry insulating material.
   b. Use a dry board, belt, dry clothing, or other available nonconductive material to free the victim from the live wire. DO NOT TOUCH the victim.
   c. After removal of the victim from the live conductor, proceed with the administration of artificial respiration as described below.

Resuscitation and Artificial Respiration

Resuscitation for electric shock. NOTE: The following instructions on resuscitation were furnished by the Bureau of Medicine and Surgery.

Artificial resuscitation, after electric shock, includes artificial respiration to reestablish breathing, and external heart massage to reestablish heart beat and blood circulation (fig. 2-1).

To aid a victim of electric shock after removing him from contact with the electricity, immediately apply mouth-to-mouth artificial respiration.



4.224
Figure 2-1.—Resuscitation procedure.

If there is no pulse, immediately apply heart massage. Don't waste precious seconds carrying the victim from a cramped, wet, or isolated location to a roomier, dryer, more frequented location. If desired, breathe into victim's mouth through a cloth or a handkerchief placed over his face. If assistance is available, take turns breathing into victim and in massaging his heart (fig. 2-1).

Cardiac Arrest (Loss of Heartbeat).—If the subject has suffered an electric shock and has no heartbeat, he has cardiac arrest. This is demonstrated by finding a complete absence of any pulse at the wrist or in the neck. Associated with this, the pupils of the eye will be dilated, and respiration will be weak or stopped. The subject may appear to be dead. Under these circumstances, severe brain damage will occur in four minutes unless circulation is reestablished by cardiac massage.

Closed Chest Cardiac Massage.—This method has been adopted as practical and can be administered by anyone who is properly instructed. The object in closed chest cardiac massage is to squeeze the heart through the chest wall, thereby emptying it to create a peripheral pulse. This must be done about 60 times each minute.

Place subject on his back; a firm surface, such as the deck, is preferred. Expose subject's chest.

Kneel beside victim; feel for lower end of subject's sternum (breastbone); place one hand across breastbone so heel of hand covers the lower part; place second hand on top of the first so that the fingers point toward neck as in figure 2-1.

With arms nearly straight, rock forward so that a controlled amount of your body weight is transmitted through your arms and hands to the breastbone. The amount of pressure to apply will vary with the subject. It should be applied as smoothly as possible. With an adult subject, the chest wall should be depressed 2 to 3 inches with each pressure application.

Repeat application of pressure about 60 to 80 times per minute.

An assistant should be ventilating the subject's lungs preferably with pure oxygen under imtermittent positive pressure; otherwise with mouth-to-mouth resuscitation. However, closed chest massage will cause some ventilation of the lungs. Therefore, if you are alone, you must concentrate on the massage until help can arrive.

Direct other assistants, when available, to keep checking the patient's pulse. Use the least pressure that will secure an effective pulse beat. The pupils will become smaller when effective cardiac massage is being performed.

Pause occasionally to determine if a spontaneous heart beat has returned.

PRECAUTIONS: Make every effort to keep the hands positioned as described in order to prevent injuries to the liver, ribs, or other vital organs.

No matter how carefully the treatment has been applied, possible chest bone damage may occur. If the patient is to be moved, it should be

done so as to prevent possible injury to internal organs by unrecognized bone fractures.

Since the heart cannot recover unless supplied with oxygen blood, it is necessary to accompany cardiac massage with mouth-to-mouth artificial respiration. When there is only one operator, the cardiac massage must be interrupted every half-minute or so to institute rapid mouth-to-mouth breathing for three or four respirations.

The mouth-to-mouth (or mouth-to-nose) technique of artificial respiration is the most effective of the resuscitation techniques.

The mouth-to-mouth (or mouth-to-nose) technique of artificial respirations is the most practical method for emergency ventilation of an individual of any age who has stopped breathing, in the absence of equipment or of help from a second person, regardless of the cause of cessation of breathing.

Persons who are trained in first-aid do not usually have the experience, training, and essential equipment to determine whether or not lack of breathing is a result of disease or accident. Therefore, some form of artificial respiration should be started at the earliest possible moment.

Any procedure that will obtain and maintain an open air passageway from the lungs to the mouth and provide for an alternate increase and decrease in the size of the chest, internally or externally, will move air in and out of a non-breathing person.

The mouth-to-mouth or (mouth-to-nose) technique has the advantage of providing pressure to inflate the victim's lungs immediately. It also enables the rescuer to obtain more accurate information on the volume, pressure, and timing of efforts needed to inflate the victim's lungs than are afforded by other methods.

When a person is unconscious and not breathing, the base of the tongue tends to press against and block the upper air passageway. The procedures described below should provide for an open air passageway when a lone rescuer must perform artificial respiration.

First, if there is foreign matter visible in the mouth, wipe it out quickly with your finger or a cloth wrapped around your finger. Tilt the head back so the chin is pointed upward (view a, fig. 2-2). Pull or push the jaw into a jutting out position (views b and c, fig. 2-2). These manuevers should relieve obstruction of the airway by moving the base of the tongue away from the back of the throat.

Open your mouth wide and place it tightly over the victim's mouth. At the same time pinch the victim's nostrils shut (view d, fig. 2-2) or close the nostrils with your cheek (view e, fig. 2-2). You may close the victim's mouth and place your mouth over the nose (view f, fig. 2-2).

Blow into the victim's mouth or nose. Air may be blown through the victim's teeth, even though they may be clenched. The first blowing efforts should determine whether or not obstruction exists.

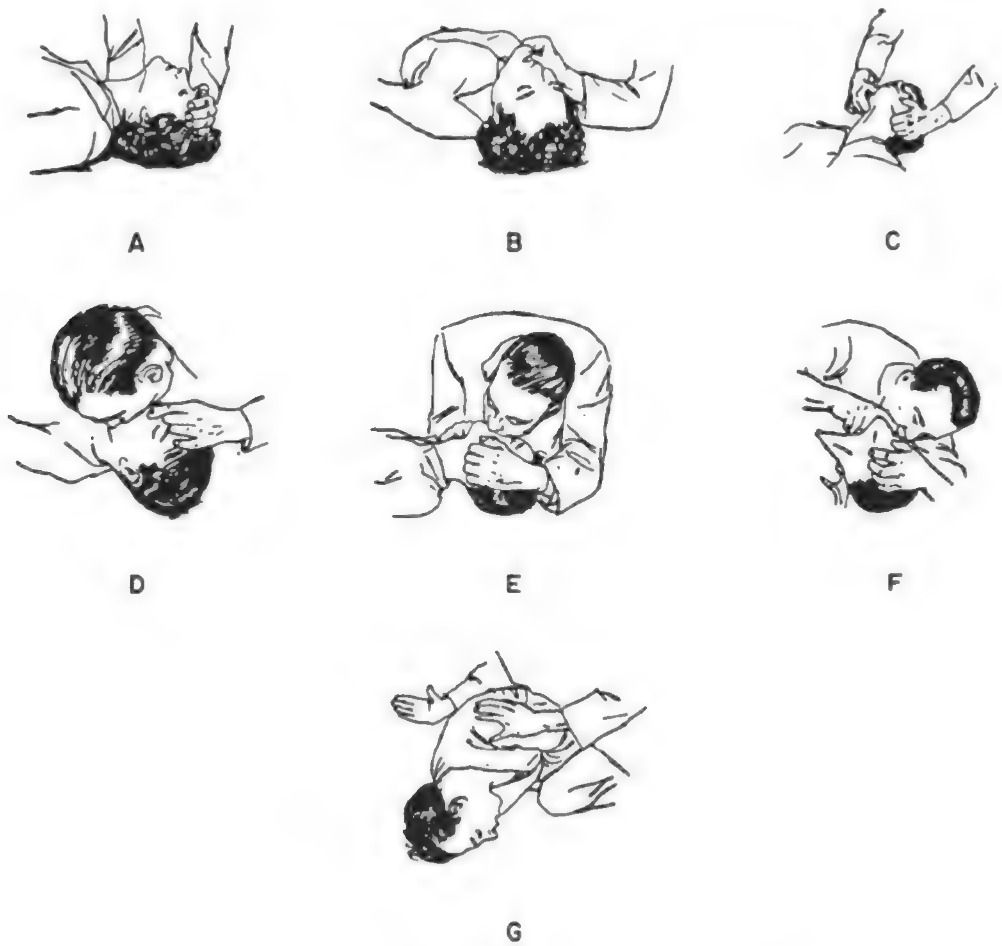
Remove your mouth, turn your head to the side, and listen for the return rush of air that indicates air exchange. Repeat the blowing effort. Blow vigorously at the rate of about 12 breaths per minute.

If you are not getting air exchange, recheck the head and jaw position. If you still do not get air exchange, quickly turn the victim on his side and administer several sharp blows between the shoulder blades in the hope of dislodging foreign matter (view g. fig. 2-2).

Again sweep you finger through the victim's mouth to remove foreign matter. Those who do not wish to come into contact with the person may hold a cloth over the victim's mouth or nose and breathe through it. The cloth does not greatly affect the exchange of air.

TAKING ON FUEL

When fueling at sea, an MM will be mostly concerned with properly manning the engineroom. The usual procedure consists of starting an extra ship's service generator, splitting the plant, manning appropriate sound powered telephones and keeping the propellers on the required r.p.m. However an MM may be assigned to a fueling station topside. You may be detailed to bring rages and sand to a fueling station to dispose of spilled oil. You may be responsible for having available spanner wrenches or other tools used in making up fuel hose connections, or in opening or closing valves. The fueling detail shall take every precaution to prevent tanks from overflowing. No leak should be neglected and any oil that may be spilled should be disposed of as soon as possible. During fueling, smoking and open flames are forbidden. Line handlers shall wear life jackets and take every precaution to prevent falling or being washed overboard.



4.224
Figure 2-2.—Mouth to mouth respiration.

WHO IS RESPONSIBLE?

Safety is everyone's responsibility. It cannot be left to an individual or an office. Everyone must always be on the alert so as not to cause an accident to himself or others.

One of the basic rules of safety requires the proper behavior of every individual. Practical jokes and horseplay cannot be tolerated. The possible consequences are too high a price to pay for the small amount of humor derived.

Another basic rule requires cleanliness, or just plain good housekeeping practices. Care must be taken to keep the decks clean and free from oil. Oil spots are very slippery and frequently result in accidents.

The assignment of a safety man is a good practice because he will spot many unsafe acts or tools that would normally go unnoticed because the men are engrossed in work with which they are familiar. It is also a good idea that the safety man be replaced periodically and the duties rotated.

Safety is a never ending job that must be emphasized so strongly that doing all jobs in a safe manner becomes the accepted and routine procedure at all times.

CHAPTER 3

STEAM TURBINES

Steam turbines are used for ship propulsion and for driving many of the auxiliary machinery units associated with the propulsion plant, such as lubricating oil pumps, condensate pumps, feed pumps, circulating pumps, fuel oil pumps, forced draft blowers, and ship's service generators.

As an MM3 or MM2, you will need a great deal of general information about propulsion plants and associated auxiliary machinery, and you will need specific information about the operation of the propulsion machinery installed in your ship.

In this chapter we will discuss in detail the main and auxiliary steam turbines from the standpoint of basic design features and operating principles. In addition, we will consider briefly the various unit or component parts, controls, and accessories of turbines used in the Navy. Turbogenerator operation and turbine maintenance are also covered in this chapter. Introduction to typical propulsion units (geared-turbine drive, turbine electric drive, and diesel engine drive), and the classification and construction of steam turbines is provided in Fireman, NAVPERS 10520-D.

STEAM TURBINE CLASSIFICATIONS

Turbine types, whether used for main propulsion power or to drive auxiliary machinery, may be classified in four ways by the:

1. Manner in which the steam causes the turbine rotor to rotate.
2. Type of staging and compounding of steam pressure and velocity.
3. Division of the steam flow.
4. Direction of the steam flow.

Under each of these classifications, there are several types of turbines, some of which are described briefly in the following paragraphs. After reading these descriptions and studying the accompanying illustrations, you should be able to classify in a number of different ways every turbine used by the Navy. A fifth method of classification, repetition of steam flow (including single entry, single re-entry, and double re-entry type turbines) is also used on some naval ships.

BY IMPULSE AND REACTION PRINCIPLES

The basic distinction made between turbines has to do with the manner in which the steam causes the turbine rotor to move. When the rotor is moved by a push or "impulse" from a high velocity jet of steam that strikes blades mounted on the periphery of a wheel, the turbine is said to be an IMPULSE TURBINE. When the rotor is moved by the force of reaction, the turbine is said to be a REACTION TURBINE. Each type however, contains a small and variable amount of characteristics of the other.

The angle at which the steam hits the moving blades and the shape of the moving blades are the two main factors which determine whether the rotor is moved primarily by a direct impulse or primarily by reaction to an impulse. Figure 3-1 shows the nozzle and blade arrangement in an impulse turbine. Figure 3-2 shows the fixed blades and the moving blades in a reaction turbine.

Impulse Turbines

In the impulse turbine, the steam expands through stationary nozzles only and so loses pressure but gains velocity. In the moving blades, the steam loses velocity but the pressure remains constant. Actually, an impulse turbine utilizes both the impulse of the steam jet and, to a lesser extent, the reactive force which results from the fact that the curving blades cause the steam

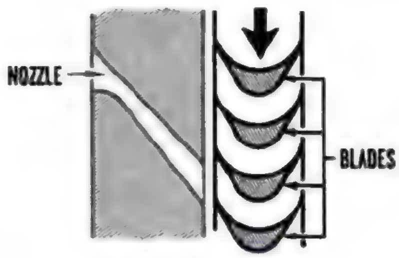


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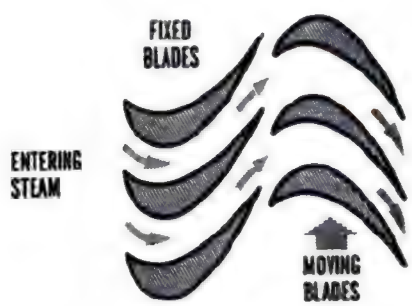
Figure 3-1.—Impulse turbine nozzle and blades.



38.77X
Figure 3-2.—Fixed and moving blades in a reaction turbine.

to change its direction. The moving blades do not serve as nozzles.

Reaction Turbines

In the reaction turbine, the steam enters through a row of fixed blades which expand and direct the flow of steam to the moving blades. As you can see in figure 3-2, the fixed blades and the moving blades are very similar in shape. Steam expansion and redirection takes place in both sets of the blades. In the reaction turbine, the steam pressure decreases in every row of fixed and moving blades.

A reaction turbine is moved by (1) the reactive force produced on the moving blades when the steam increases in velocity, and (2) the reactive force produced on the moving blades when the steam changes direction. However, some of the motion of the rotor is actually caused by the impact of the steam on the blades; and, to a certain extent, therefore, the reaction turbine operates on the impulse principle as well as on the reaction principle.

Basic Differences Between Impulse and Reaction Turbines

Now let us take time to compare the basic differences between impulse- and reaction-turbine blading. No matter what the number of nozzles and moving blade rows in an impulse turbine, the pressure remains the same throughout the rotor blading of each stage. There are no nozzles in the reaction turbine; the fixed and moving blades serve the same purpose as the nozzles of an impulse turbine.

BY STAGING AND COMPOUNDING

Simple impulse turbines, which are single stage units, have the advantage of being simple in design and construction. They are often used for small auxiliary units. The simple impulse stage consists of one nozzle row and one moving row and is usually called a RATEAU STAGE.

The velocity-compounded impulse turbine, which has two rows of moving blades, has only one pressure drop and therefore, by definition, only one stage. This type of velocity-compounded impulse stage is usually called a CURTISSTAGE. Most surface ship's auxiliary turbines used for pumps and forced draft blowers consist of one CURTIS STAGE.

(Velocity-compounding can also be achieved when only one row of moving blades is used, provided the steam is directed in such a way that it passes through the blades more than once. This point will be taken up in greater detail in the discussion of types of steam flow.)

A pressure-compounded impulse turbine is often called a RATEAU TURBINE, since it is essentially a series of simple impulse (Rateau) stages arranged in sequence in one casing. Pressure compounded impulse turbines are not commonly used for small auxiliary units; however, they are prevalent in submarines and modern ships propulsion turbines. With equal steam inlet and exhaust conditions, the rateau turbine may be somewhat more efficient, having a smaller pressure drop per stage and may be somewhat longer than a turbine using curtis staging.

The COMBINATION IMPULSE AND RE-ACTION-ACTION TURBINE employs a velocity-compounded impulse (Curtis) stage at the high pressure end of the turbine. This effects large

temperature and pressure drops in the first-stage nozzles, as well as a high initial utilization of thermal energy. It also enables the remaining pressure-compounded impulse or reaction stages of the turbine to work more efficiently and with less tendency to thermal distortion in the turbine parts. In turn, clearances and clearance leakages are relatively smaller. Figure 3-3 illustrates diagrammatically the design of this type of turbine, which is often referred to as a MODIFIED PARSONS TURBINE.

BY DIVISION OF STEAM FLOW

The next classification of turbines concerns the number and type of divisions in the steam flow through the several elements which comprise the complete turbine. The turbine types under this classification include single-flow turbines, cross-compounded turbines, and double-flow turbines.

Single-Flow Turbines

In single-flow turbines, the steam enters at the inlet or throttle end, flows once through the blading in a line approximately parallel to the rotor or shaft, and emerges at the exhaust end of the turbine. Figure 3-4 illustrates this type of turbine.

The steam passing through a multistage impulse turbine produces an axial thrust of roughly 36 percent, depending on nozzle exit angle. The equalizing holes help to diminish this axial thrust in an impulse turbine. It is also diminished by interstage leakage. The remaining thrust in a modified PARSONS TURBINE is opposed by axial thrust from the reaction blades. It should be noted also that axial thrust in impulse blading is opposite to axial thrust in reaction blading since the pressure drop actually takes place in the nozzles. The EQUALIZING HOLES provided in the turbine

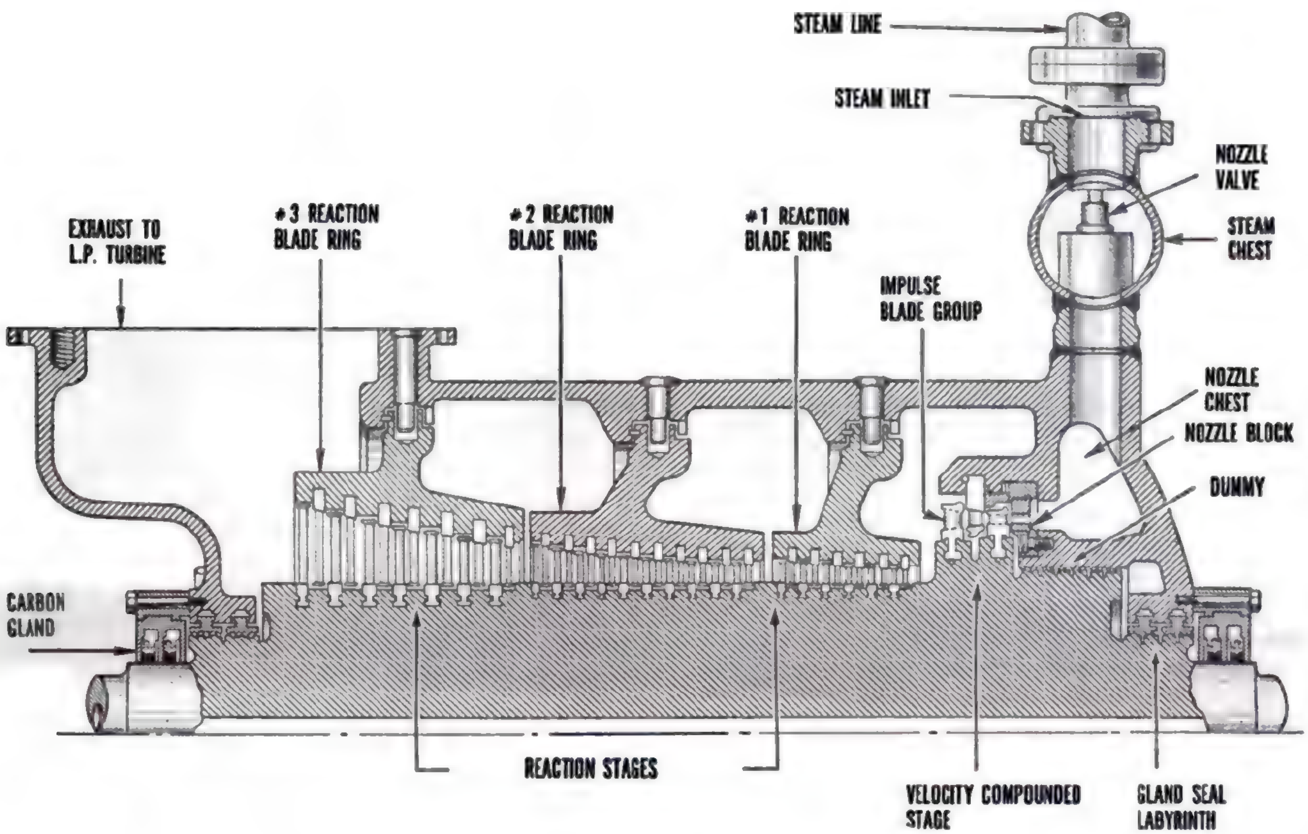


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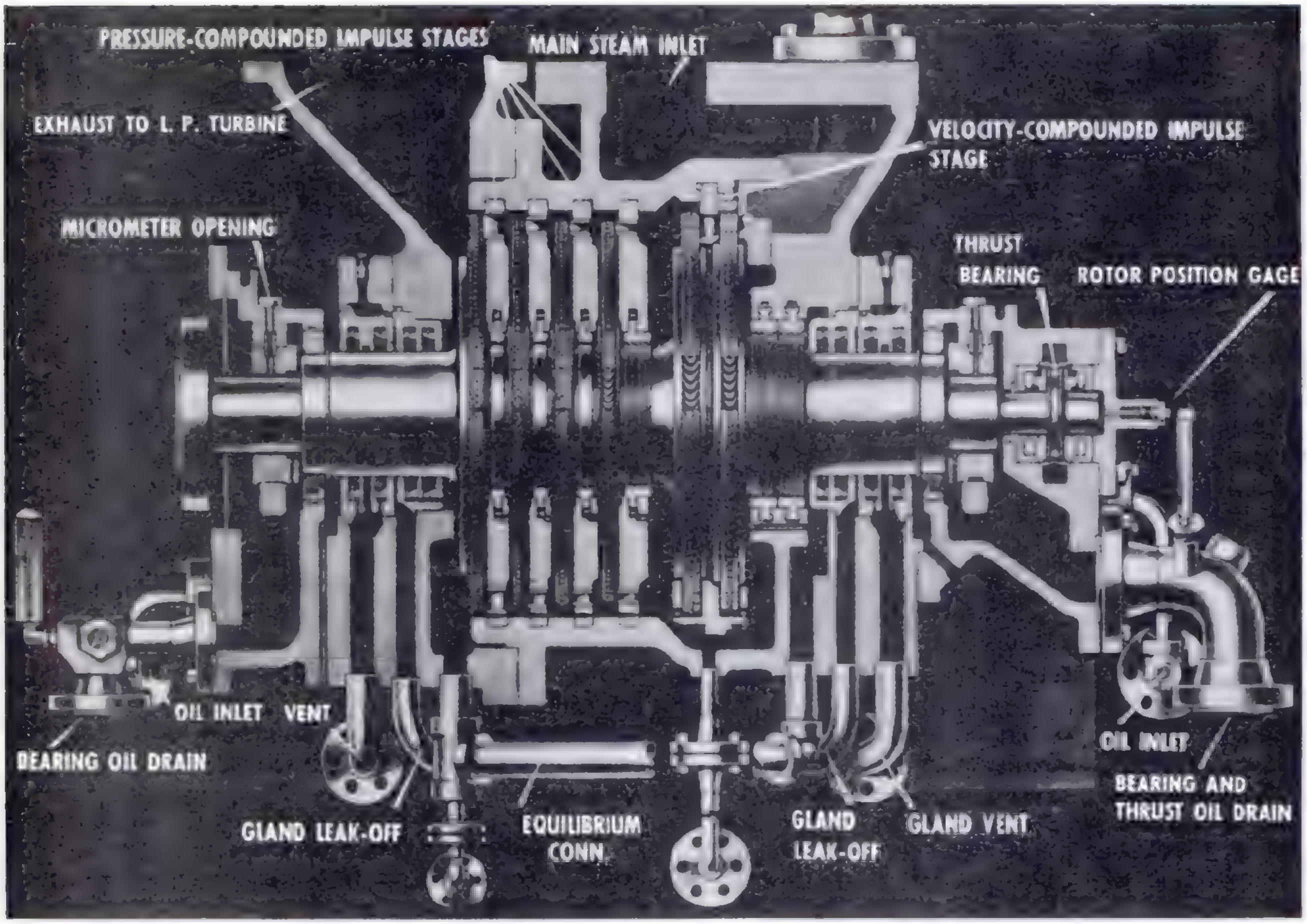
Figure 3-3.—Combination impulse and reaction turbine.



47.4

Figure 3-4.—Single-flow pressure velocity compounded impulse turbine.

wheel also help to prevent the development of axial thrust upon the individual wheel of the rotor. In a reaction turbine, however, considerable axial thrust does result from the steam pressure drop since the pressure drop occurs in the moving blades as well as in the stationary blades. In single-flow reaction turbines, this axial thrust is partially counterbalanced by use of a dummy piston and dummy cylinder arrangement such as is shown in figure 3-5. In this arrangement, the space A, which surrounds the inlet end fact area of the turbine rotor, is connected to space B, which surrounds the outlet face end area of the rotor, by an equalizing pipe. The dummy piston and cylinder which form a close running sealing-surface serve to prevent the entry of large amounts of steam from the inlet passage into space A. (The equalizing pipe pressure times the effective area of space A acts to push the rotor toward the exhaust end thereby roughly counterbalancing the thrust in the other direction due to pressure reaction in the blading. This counterbalance varies as the turbine power varies, and is seldom in perfect equilibrium.)

In some types of combination impulse and reacting turbines, as for example figure 3-3, a dummy piston and dummy cylinder arrangement similar to the one just described was used to help offset the axial thrust effect caused by the reaction blading of the turbine. In reaction turbines of the double-flow type, which are discussed later in this chapter, the dummy piston and cylinder are not necessary since the axial thrusts developed at each end counterbalance each other.

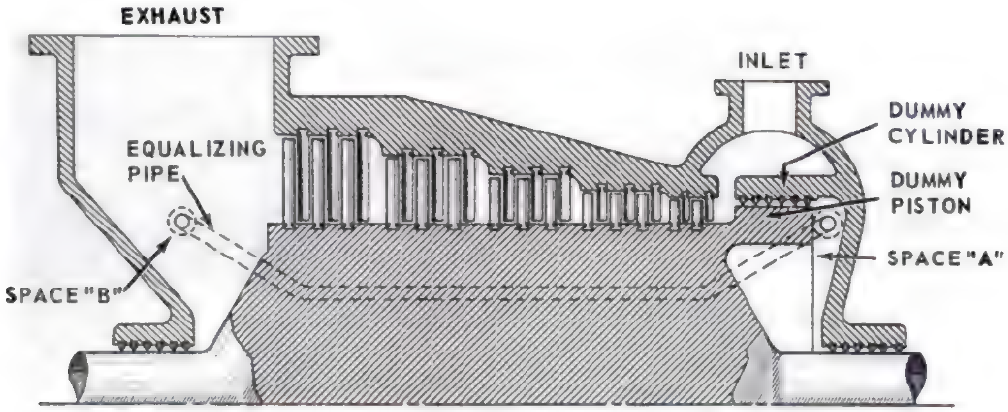


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Figure 3-5. — Dummy piston and dummy cylinder.

Double-Flow Turbines

Single-flow turbines with a large capacity and a low exhaust pressure require excessively long blades (or a very large turbine diameter) at the low pressure stages to allow free passage of the expanded steam, and to maintain the desired_ efficiency. To overcome these disadvantages, LOW PRESSURE TURBINES are frequently constructed as a double-flow type. This type of turbine, shown in figure 3-6, consists of two single-flow units installed on one shaft, in the same casing, with steam inlet at the center and the exhaust at both ends. The blading is arranged to permit steam flow from the center toward both ends, and to give the rotational effect in the same direction at both ends.

Since equal amounts of steam flow from the center toward each end in the double-flow turbine, the steam thrust (pressure toward end of turbine) is balanced, and the undesirable axial thrust is eliminated. Low pressure compound turbine units are of 30,000 SHP and above are normally of

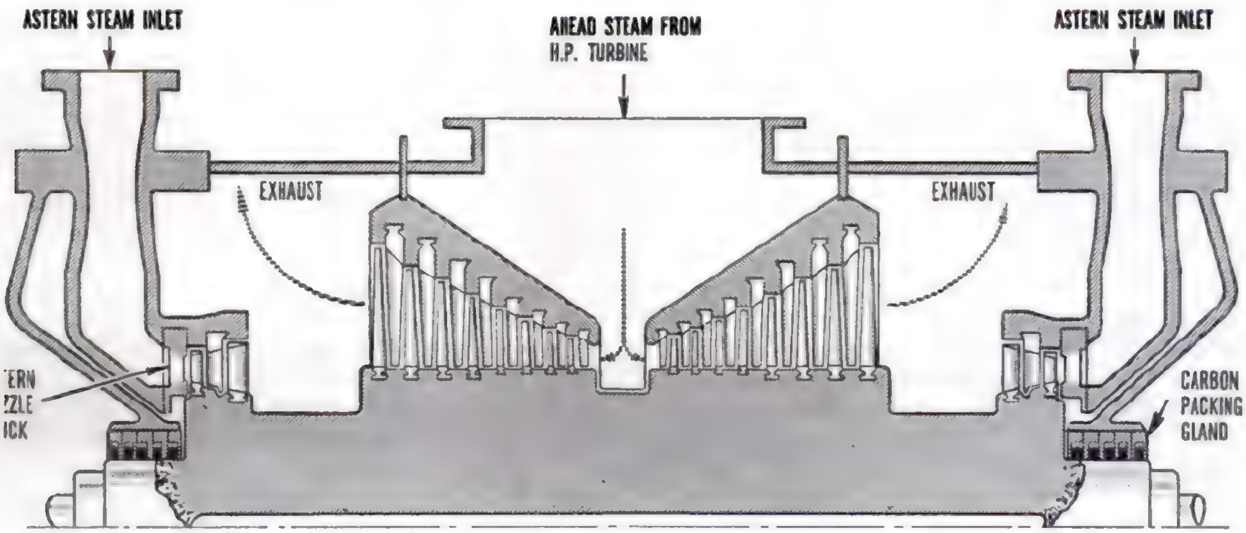

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Figure 3-6. — Low pressure double-flow reaction turbine.

this type of construction. For lower power units, single flow low pressure turbines with the astern turbine in one end are used.

Astern (Backing) Turbines

Astern turbines are usually one-, two-, or three-row impluse turbines (some full Curtis, some Curtis-Rateau), and they develop about one-fifth to one-half of the maximum power of the ahead turbines.

In noncombatant surface ships, the astern turbine usually consists of one or two velocity-compounded impulse (Curtis) stages mounted on one end of the low pressure ahead turbine rotor.

Modern surface type ships with geared turbine installations have an astern element of one or more velocity-compounded stages installed at each end of the low pressure rotor. This dual element provides higher astern power than is possible with a single astern element. In addition, the axial thrust developed by one element is opposed and balanced by an equal axial thrust developed by the other element. It is obvious that astern blading, when mounted on the same rotor as ahead blading, must reverse the rotation of the rotor. This is done by simply directing steam flow to the astern elements.

Typical submarine turbine consists of a single rotor with ahead impulse blading at one end and astern impulse blading at the other.

Normally, steam should not be admitted to the backing or astern turbine while steam is being admitted to the ahead turbines. (See fig. 3-7.) However, in emergency situations (such as "crash astern" or "crash ahead") steam may be admitted to both ahead and astern turbines while one throttle is being closed and the other opened.

Cross-Compounding of Turbine Units

In turbine units of small or moderate power, complete expansion of the steam, and resultant utilization of the latent energy, can be provided for in a single casing such as in most submarines. For greater power requirements, however, this type of turbine would require casings and rotors of such great size as to create serious difficulties in construction. The weights of these parts would also be so great that required assembly and disassembly for inspection and overhaul would be very difficult. These units are not cross-compounded.

There were originally two general types of compound turbine units in use—the cross-compound and the tandem-compound—but the cross-compound type is the only one now used in the Navy. In these CROSS-COMPOUND TURBINE installations (fig. 3-8), the high and low pressure units are on separate shafts. The two turbine shafts are connected, through reduction gears, to a common shaft which drives the ship's propeller.

High-power geared turbine installations are, therefore, generally built as compound turbine units. In this type, the steam is partially expanded in a HIGH PRESSURE TURBINE (enclosed in a casing of its own), and then exhausted, through a crossover pipe, to a LOW PRESSURE TURBINE where the expansion is completed. The energy-depleted steam is then exhausted to the main condenser. In some instances, a CRUISING TURBINE precedes the high pressure turbine. This turbine is used when operating within the cruising speed range (for economy reasons) before exhausting into the high pressure turbine, and may be bypassed at higher powers or speeds.

CRUISING TURBINES are similar in design to the high pressure turbines, except that the cruising turbines are smaller in size. When cruising turbines are in use, steam passes first through the cruising turbine before going to the high pressure turbine (fig. 3-9). In this way, the steam is expanded through a greater number of pressure stages. This extracts more energy from the steam than is possible by use of the high pressure and low pressure turbines. When speeds in excess of the cruising turbine's range are desired or anticipated, the steam is led directly to the high pressure turbine, by-passing the cruising turbine, as shown in figure 3-10. Cooling steam is supplied to the cruising turbine from the high pressure turbine to prevent damage from overheating caused by friction of rotation. Reduction gears and shafting are used to connect the high pressure turbine and the cruising turbine. By disconnecting at the reduction gear, the cruising turbine can be isolated from the power plant. The propulsion turbines in the DD 445 class and DD 692 class of ships contain cruising turbines.

Frequently, a series-parallel turbine design is being used. It consists of a single high pressure-intermediate pressure rotor and casing, and a conventional low pressure unit. The high pressure-intermediate pressure steam chest and nozzle control valves are arranged

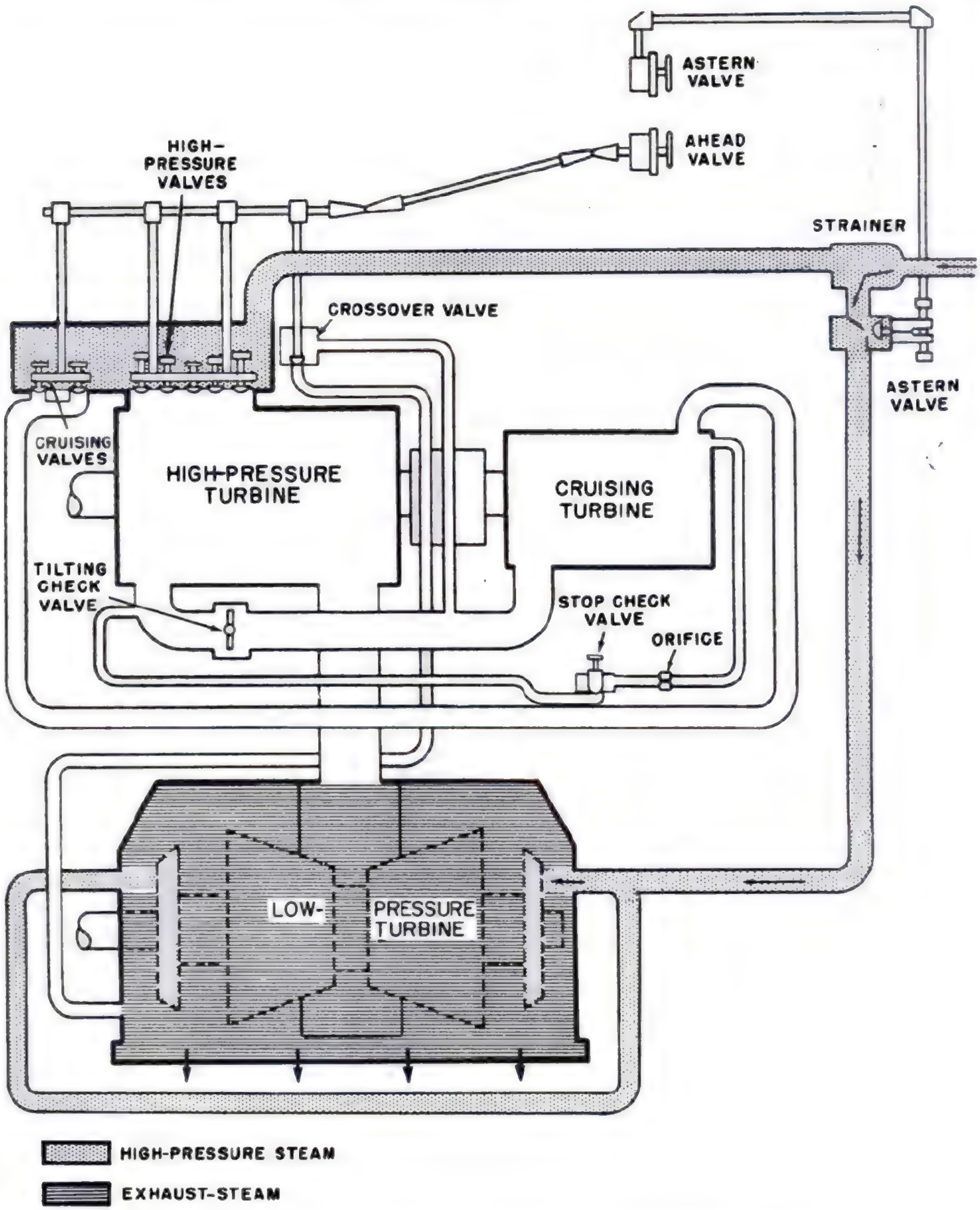

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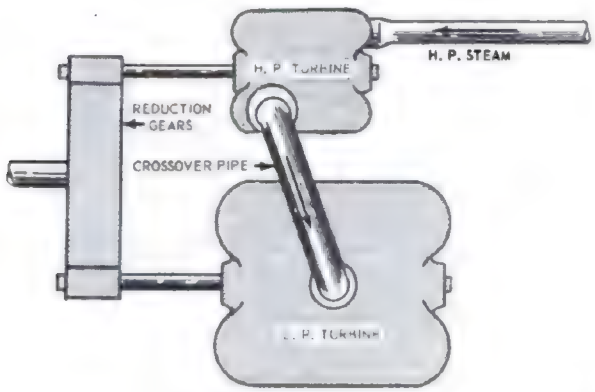
Figure 3-7.— Flow of steam in propulsion unit (astern operation).



47.6
Figure 3-8.—Diagrammatic arrangement of a cross-compounded turbine.

so that steam is admitted only to the high pressure element for speeds in the cruising range. The steam then passes through an external pipe to the intermediate pressure element and is exhausted to the low pressure unit. For this condition, the turbine is said to be operating in series. For speeds in excess of the cruising range, main steam is admitted to both the high pressure and intermediate pressure elements simultaneously and the turbine is operating in parallel. Both the high pressure and intermediate pressure elements exhaust separately through a crossover pipe to the low pressure element.

BY DIRECTION OF STEAM FLOW

Turbines may be classified as axial flow, helical flow, or radial flow, according to the direction of the flow of steam relative to the turbine wheel. The Navy uses only the axial flow type for main propulsion units; helical flow turbines are widely used for driving auxiliary machinery; and radial flow turbines are used to a limited extent for small pump drives.

Axial Flow Turbines

Most steam turbines (especially those of medium and high power), and all of those we have thus far discussed, are of the axial flow type. In such turbines, as the terminology implies, the steam flows in a direction approximately parallel to the axis of the rotor, the blades being set so that they project radially from the periphery of the rotor or wheel.

As already indicated, the desired degree of steam expansion in this type turbine is provided for by: increasing the number of rows of blades; increasing the length of blades in successive rows; changing the shapes of the blades or variously spacing them; or a combination of two or more of these methods.

Helical Flow Turbines

In the helical flow (tangential) turbine, the steam flows in the form of a spiral or helix. The rotating element consists of a wheel having semicircular slots, or "buckets," milled obliquely in its periphery or outside circumference. The nozzles (fig. 3-11) are located in such a manner around the circumference of the wheel that the steam flows from them in a direction approximately tangent to the wheel, or so that it impinges upon the slots of the wheel. In this way, the steam is directed into the buckets, and gives a rotational impulse to the wheel. The moving buckets are so shaped that the direction of the steam flow is reversed within them, and the steam is sent back out of the side opposite from where it entered.

The steam coming out of the moving buckets is caught in stationary buckets or REVERSING CHAMBERS, where its direction is again reversed and the steam flows back through the moving buckets. This reversing and redirecting process is repeated several times, after which the steam passes out through the exhaust opening.

A nozzle and the accompanying set of fixed redirecting buckets or reversing chambers are cast or welded in one place. Up to the limit imposed by the circumference of the wheel, any number of these nozzle and bucket sets may be installed. Since the only drop in pressure occurs in the nozzle, this turbine is a single-stage, velocity-compounded, impulse turbine.

This type of turbine is built only in small units, up to a few hundred horsepower, and is used for driving such auxiliary machinery as pumps and forced draft blowers. It has reasonably high efficiency over a wide range of speeds, and is especially adapted to units requiring large speed variations in normal operation.

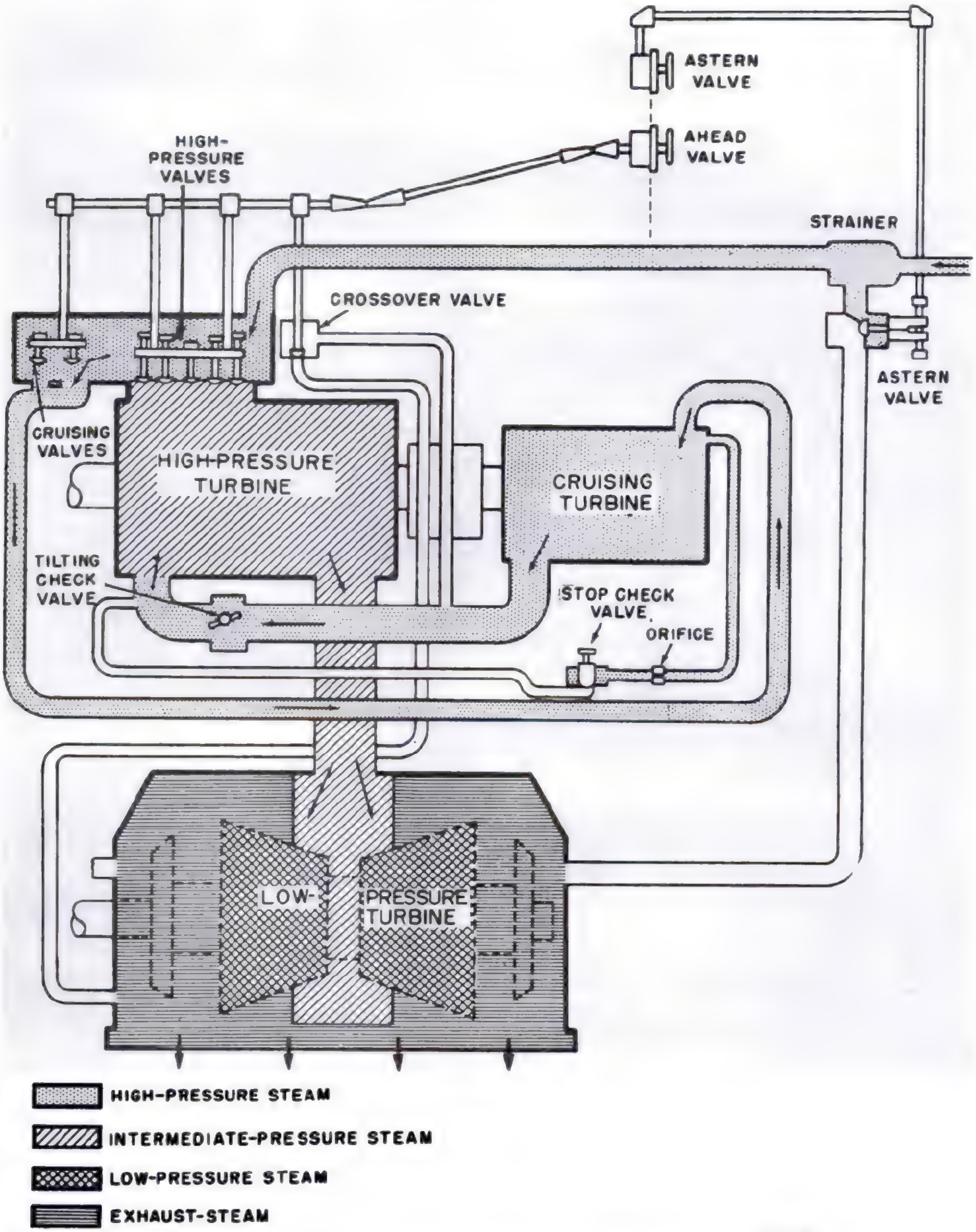


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Figure 3-9. — Flow of steam in propulsion unit (cruising turbine in use).

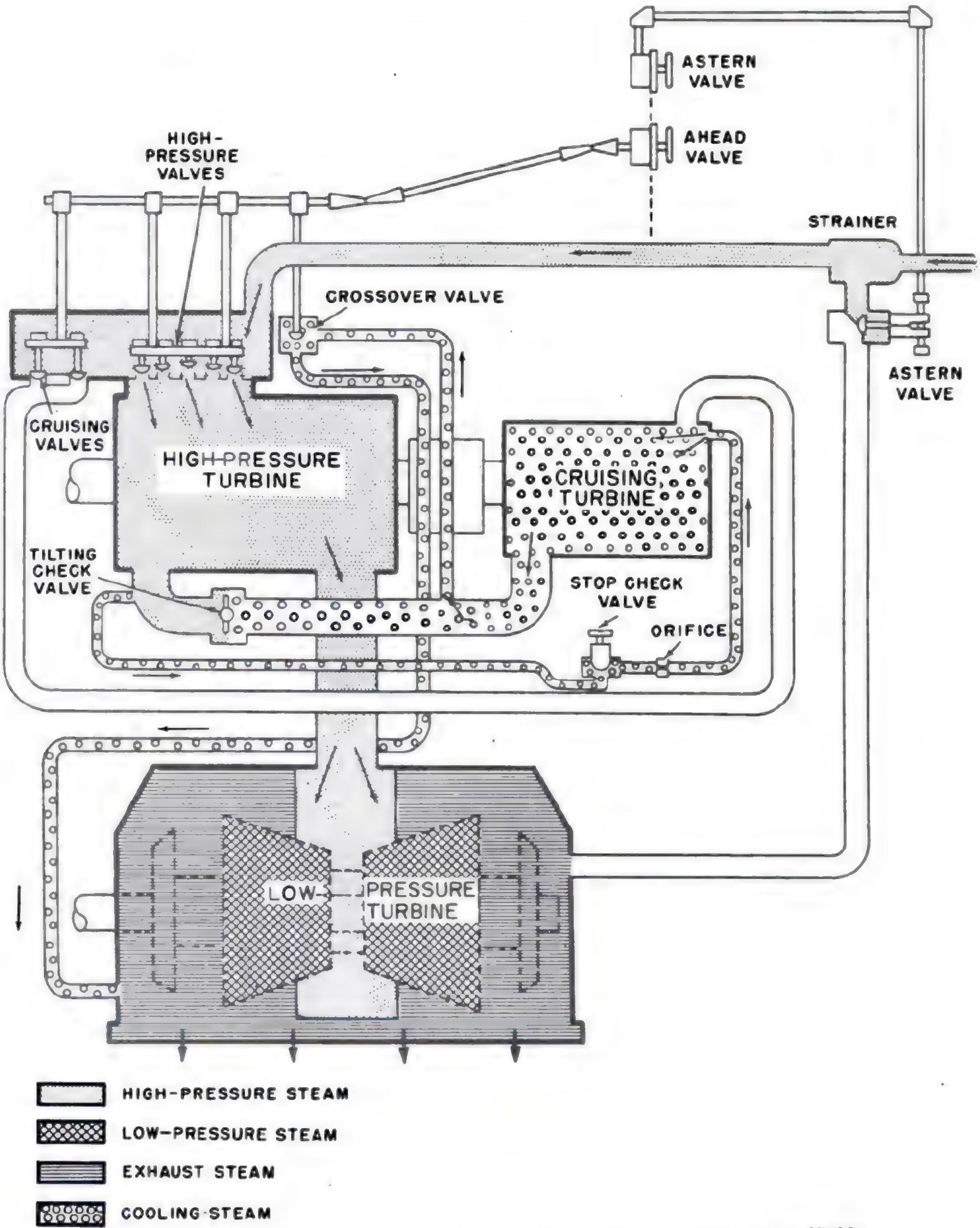

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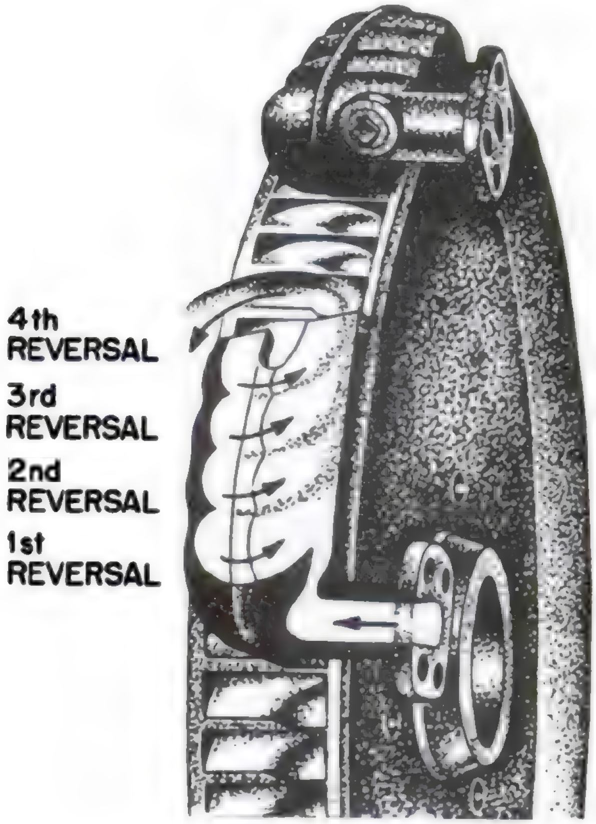
Figure 3-10.—Flow of steam in propulsion unit (cruising turbine not in use).



33.45X
Figure 3-11.—Phantom view of steam path in a Sturtevant helical flow turbine.

AUXILIARY STEAM TURBINES

The preceding portions of this chapter have described the general principles and construction features of the various types of turbines in use by the Navy, with particular (though not exclusive) emphasis on the larger types of turbines used for main propulsion. There are, of course, a considerable number of small turbines employed in all naval engineering plants for driving auxiliary machinery such as generators, pumps, air compressors, and forced draft blowers.

Most auxiliary machinery units outside the engineering spaces on modern naval ships, and many units within these spaces, are driven by electric motors. For example, the usual practice is to duplicate some turbine-driven pumps with electrically driven units to be used at cruising speeds and in port. These motor-driven pumps have a comparatively high efficiency, but on some ships their capacity is not great enough to meet the demands of the engineering plant at high speeds.

EFFICIENCY OF AUXILIARY TURBINES

Turbine-driven units (particularly pumps) have a higher capacity than the motor-driven units. Two additional reasons for employing turbines to drive the auxiliary machinery are as follows:

1. Turbines ensure greater reliability than motor-driven units. The possibility of interruption or loss of electric power supply is greater than the possibility of loss of steam supply—especially during General Quarters and special details.
2. Turbines improve the over-all efficiency of the plant by supplying exhaust steam for such auxiliary machinery units as deaerating feed tanks and evaporators, where low pressure is required.

The efficiency of most auxiliary turbines is increased with the use of reduction gears. Those turbines are designed to have comparatively few stages (sometimes only one), to conserve space. This results in a large pressure drop in each stage, and a high steam velocity. To obtain maximum efficiency, the blade speed must also be high. Hence, the reduction gears reconcile the two conflicting speed requirements, and increase the general efficiency.

AUXILIARY TURBINE CLASSIFICATION

In general, auxiliary turbines in naval use may be classified (in a manner similar to the general turbine type classifications) according to the following characteristics.

1. Speed (constant or variable).
2. Exhaust conditions (condensing or non-condensing).
3. Shaft position (horizontal or vertical).
4. Type (impulse or reaction).
5. Steam flow direction (axial, radial, or helical).
6. Stages (single or multiple).
7. Drive (direct or geared).
8. Service (based upon driven auxiliary).
9. Power output capacity, limiting speeds, etc.

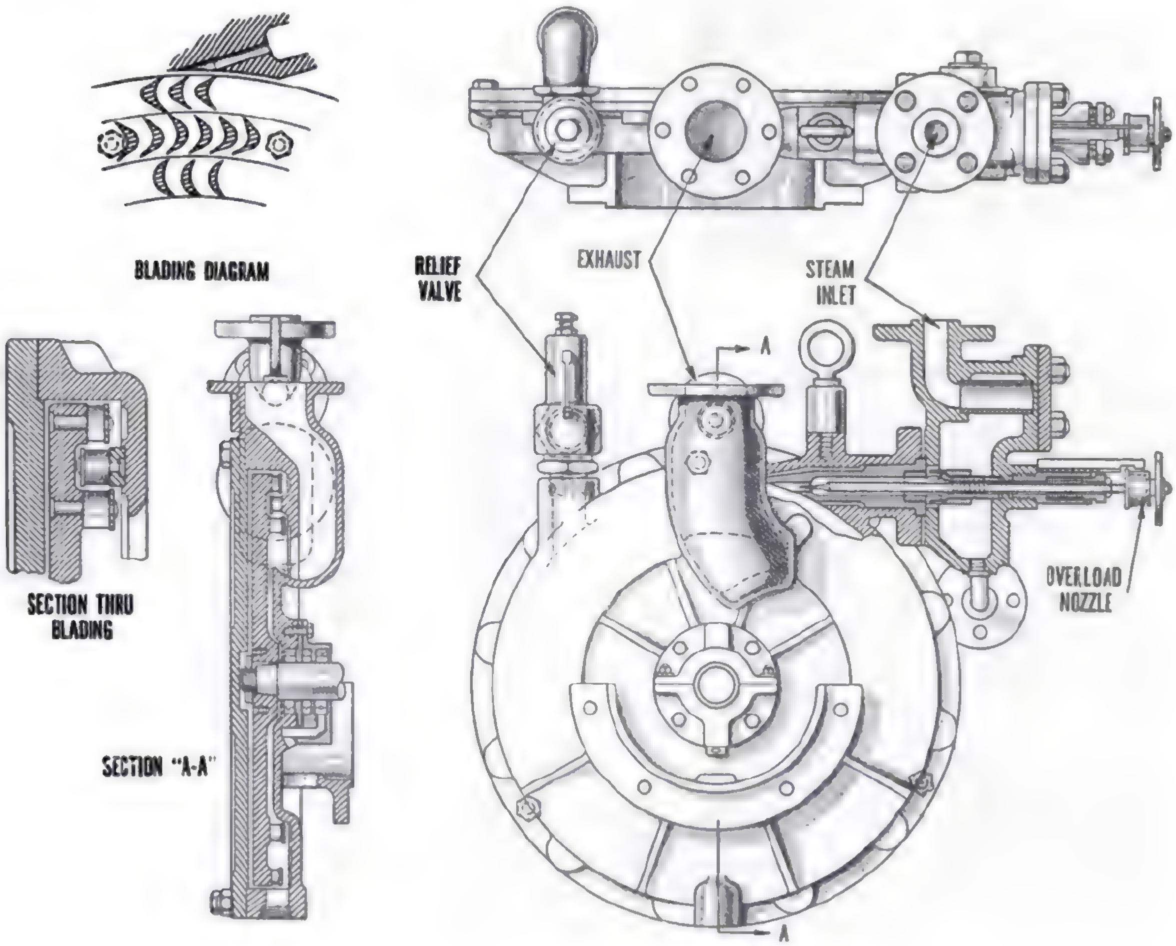
Except for turbine-driven electric generators, the auxiliary turbines are usually impulse turbines of either the helical-flow or axial-flow type. They operate against a back pressure of approximately 15 psig, depending upon the auxiliary exhaust line operating pressure of the ship in which installed. In later ships, this back pressure is 15-17 psi. Turbines for driving the ship's service generators are ordinarily of the impulse, axial-flow, multistage, geared type.

USES OF AUXILIARY TURBINES

Since the various types of turbines were discussed in the earlier part of this chapter, it is unnecessary to explain in detail construction of the various auxiliary turbines utilized to drive the numerous pumps in the engineering spaces of your ship. The principal pumps driven by the condensate pumps, however, include the main condensate pumps, main condenser circulating pumps, main feed pumps, main feed booster pumps, main fuel oil service pumps and forced draft blowers.

Main Condensate Pump Turbines

On some ships the turbines driving the main condensate, main feed booster, and the lube oil service pumps are identical. The bucket wheels (turbine wheels) and many other parts such as governors, bearings, and turbine and gear casings are interchangeable. Figure 3-12 shows the wheel and blading diagram of a turbine



47.9
Figure 3-12.—Main lube oil pump turbine.

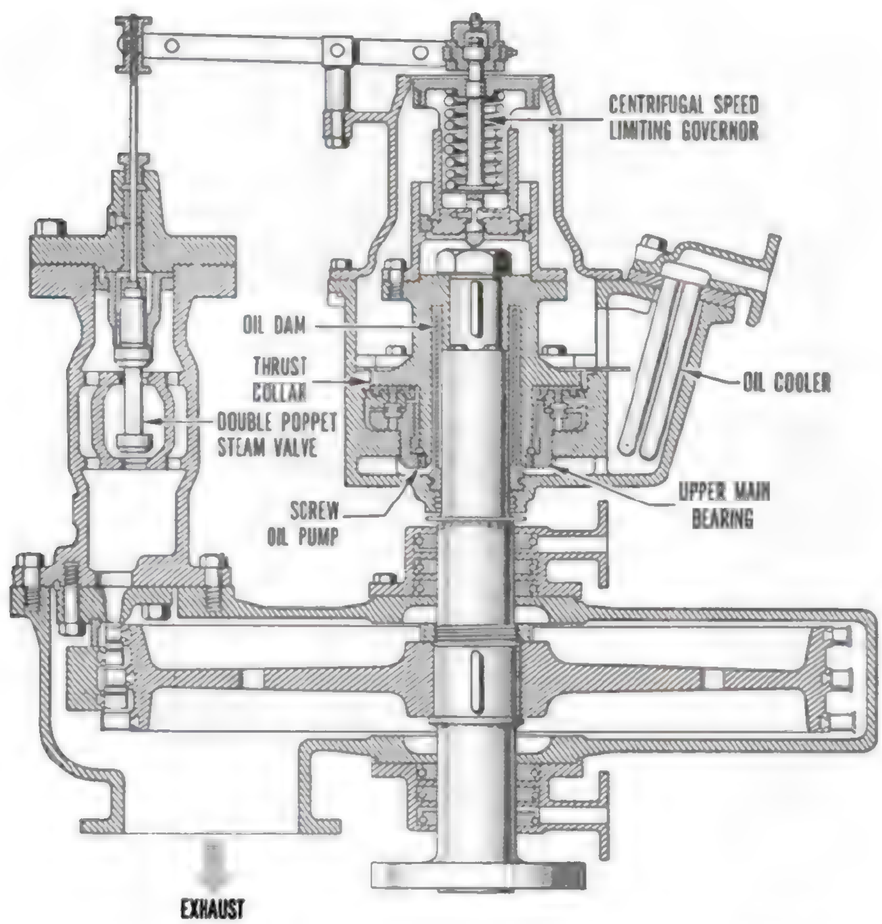
used to drive the main condensate, main feed booster, and lube oil service pumps on a DD-692 class destroyer. These turbines are single pressure stage, radial flow single entry turbines. Although destroyers and other ships have changed radically since World War II, the basic design of these turbines has changed little. Improved metals are used, however, to withstand the higher pressures and temperatures of steam on modern warships.

Main Condenser Circulating Pump Turbine

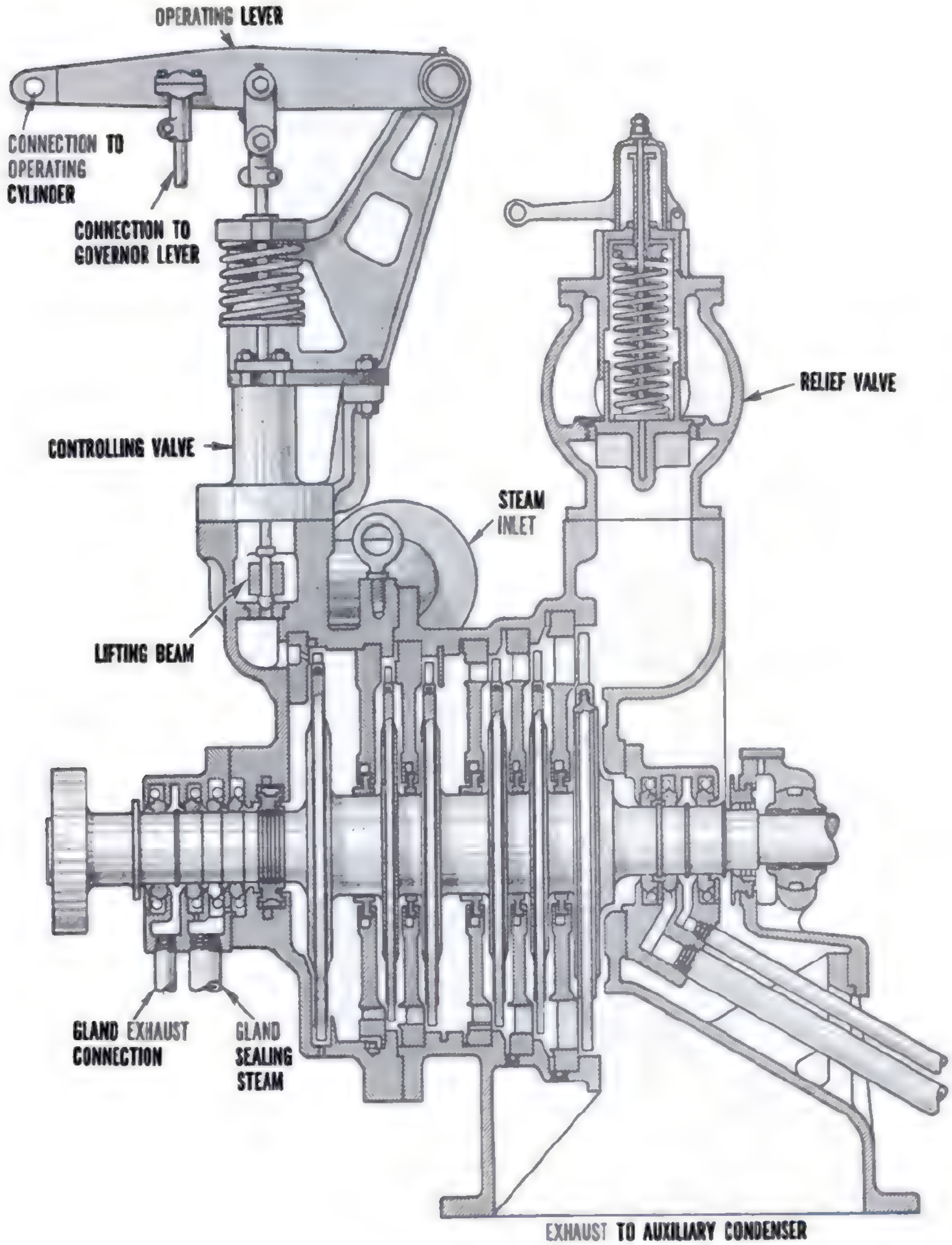
Figure 3-13 shows a vertically mounted, single stage, axial flow, velocity compounded, impulse unit. The turbine shaft is coupled to the vertical shaft or the pump. A thrust bearing, mounted integrally with the upper main bearing, carries the weight of the rotating element, and absorbs any unbalanced downward thrust. A throttle valve and a double-seated balanced inlet valve (normally held wide open by governor mechanism) let the steam into the turbine.

Generator Turbines

Figure 3-14 shows a turbine used to drive a 400-kilowatt a-c, 50-kilowatt, d-c, generator. The turbine is an axial flow, pressure compounded, impulse type. It exhausts to a separate auxiliary condenser having its own circulating and condensate pumps and air ejector. Cooling water for the condenser is provided by the auxiliary circulating pump, through separate injection and overboard valves. On some ships when a casualty to the auxiliary condenser



47.10
Figure 3-13. — Main condenser circulating pump turbine.



47.11X
Figure 3-14. — Ship's service generator turbine.

occurs, the turbine may exhaust to the main condenser, while the main plant is in operation.

A relief valve is always installed on the turbine exhaust casing to relieve excess pressures which would build up within the turbine casing if for some reason the exhaust valve should be inadvertently closed or a loss of vacuum should occur.

The turbine is so designed that it can operate on either saturated or superheated steam at a pressure of 525 psi, and at a maximum temperature of 825°F at the throttle. On most ships provision is made for supplying steam to the turbine from either the main steam line (superheated) while underway, or the auxiliary steam line (saturated) during in-port operation, when the main engines and main steam lines are secured. The steam is admitted to the turbine through a throttle trip valve to the steam chest—the speed being regulated by a number of nozzle control valves under the control of a governor. This type of control is explained in a later section of this chapter.

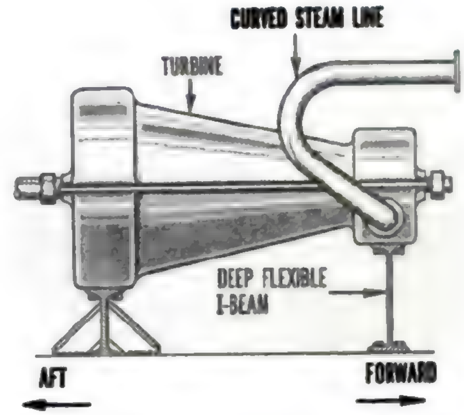
There are so many variations of generator turbines that it is necessary to consult the manufacturer's technical manual for details of construction, operation, and maintenance of any specific unit.

TURBINE PARTS

Now that you are familiar with the variety and diversity of turbines used in the Navy, the component parts, controls, and accessories of these turbines will be covered briefly in the sections which follow. At this point, however, it should be noted that the information which follows is supplementary to that given in Fireman, NAVPERS 10520-D.

Foundations, casings, valves, nozzles, wheels and rotors, blading, bearings, shaft glands, and gland seals are turbine parts common to impulse and reaction turbines.

The forward end of a turbine may be secured to a deep FLEXIBLE I-BEAM (fig. 3-15) installed with its axis lying athwartship. When the turbine is operating at a pre-selected power this I-beam stands in a vertical undeflected position of minimum stress. When the turbine operates at other powers, and therefore other temperatures, the I-beam is deflected slightly forward or aft of the vertical position and with increased stress. The fixed end of the turbine is usually aft and opposite to the thrust bearing so that motion due to forward expansion of the



47.12X
Figure 3-15. — Turbine foundation, showing flexible I-beam.

casing will neutralize the aft expansion of the rotor. Thus, damage to the reduction gear from unmeshing of the pinions is minimized. Keys located forward and aft on the longitudinal centerline of the turbine provide a fixed line for athwartship expansion. Vertical expansion features usually used the turbine support bolting as the fixed point. STEAM LINES connected to the turbines are bent (as shown in fig. 3-15) to allow for expansion of the steam line and due to heat and to relieve strain on the turbines resulting from otherwise uncompensated expansion. Corrugated pipe sections called expansion joints are also used if the pipe bends are insufficient.

On many ships, the main condenser is supported by the low pressure turbine which is rigidly mounted on beams which form an integral part of the hull structure. In other ships, the low pressure turbine may be mounted on the condenser which, in turn, forms an integral part of the hull. In general, the expansion arrangement of the low pressure turbine is similar to that of the high pressure except that the flexible forward support is seldom used. Instead, some arrangements use keys at the center of the low pressure casing as the fixed point with expansions occurring equally in the forward and aft directions from the keys. Some arrangements fix the after end of the casing by fitted bolts while the forward end uses clearance bolts to allow for the expansion motion. Another arrangement uses fitted bolts at each end; these bolts fix the ends to flexible twin inlet necks on the condenser.

NOZZLE DIAPHRAGMS

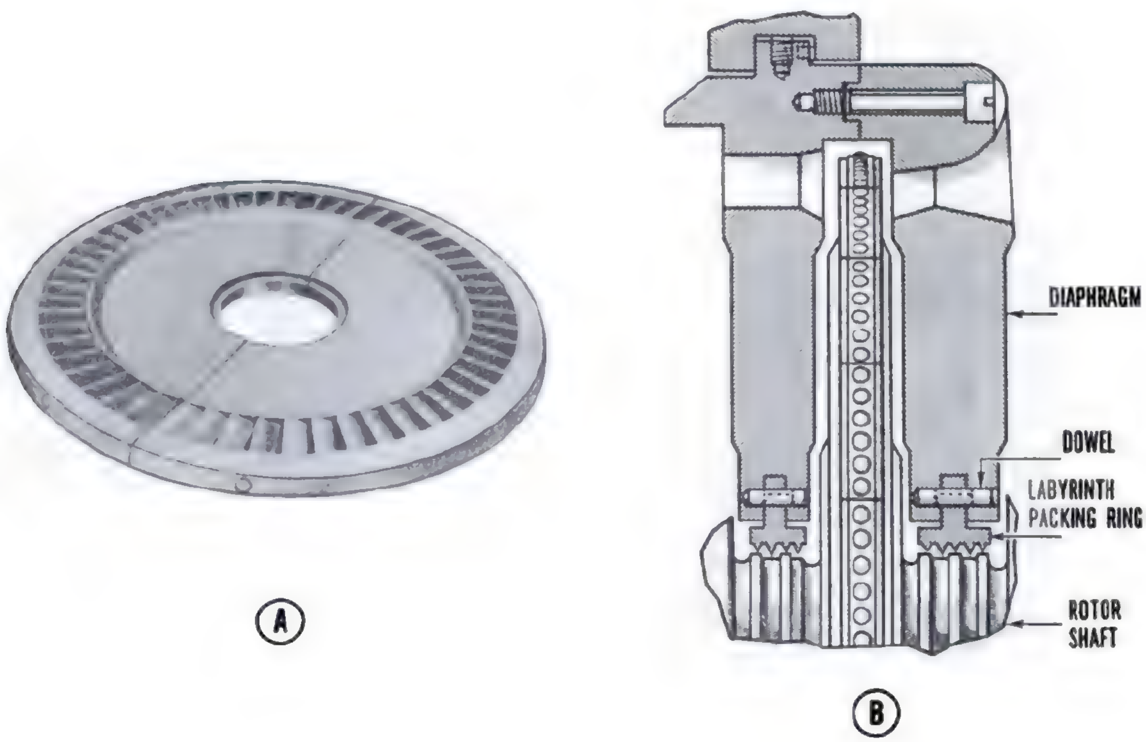
Nozzle diaphragms, illustrated in part A of figure 3-16, are installed ahead of the rotating blades of each stage of a pressure-compounded impulse turbine. These contain the nozzles and admit steam to the rotating blades of each stage in much the same way as the nozzle groups of the first stage. Some nozzle diaphragms admit steam in an arc of a circle and are called PARTIAL ADMISSION diaphragms; other nozzle diaphragms, however, have nozzles extending around the entire circle of blades and are called FULL ADMISSION diaphragms. The pressure drop existing across each diaphragm necessitates the installation of a rotor packing seal to minimize the leakage of steam across the diaphragm and along the rotor. For this purpose a labyrinth packing ring, similar to the shaft gland packing, is placed in a groove in the inner periphery of the diaphragm. Part B of figure 3-16 illustrates the placement of these rings which are installed in sections and are spring-backed to effect a good seal.

BEARINGS

The rotor of every turbine must be positioned radially and axially by bearings. Radial bearings carry the weight of the rotor, and maintain the correct radial clearance between the rotor and the casing. Thrust bearings limit the axial movement of the rotor. Both types are briefly discussed in the sections which follow.

Radial Bearings

Most turbines, including all main turbines, have a radial bearing at each end of the rotor. These bearings are generally known as JOURNAL BEARINGS, sleeve type or tilting pad type. Each type may be either cylindrically-seated or spherically-seated. Some small auxiliary turbines employ what is known as ANTIFRICTION BEARINGS, including ball and roller bearings. This discussion, however, is limited to friction type bearings, where dissimilar metallic surfaces are separated by and depend

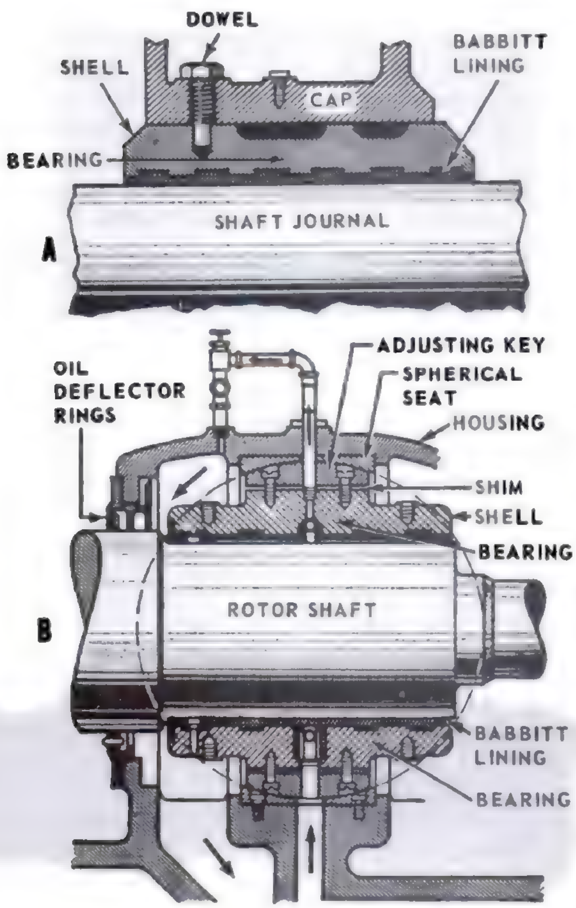


47.14X
Figure 3-16. — Turbine nozzle diaphragms. A. Impulse nozzles and nozzle diaphragms. B. Internal construction.

upon an intervening fluid oil-film for lubrication and cooling.

The effectiveness of this FLUID FILM LUBRICATION, as illustrated and explained in Chapter 9, "Lubrication and Associated Equipment," depends upon a number of factors: the lubricant's properties of cohesion, adhesion, and viscosity; its temperature; its cleanliness; and the clearance, alignment, surface condition of the bearing and journal, load, and speed. Except for the momentary metal-to-metal contact at the time the turbine is started, the two metallic surfaces of the journal and bearing are constantly separated by a thin film of oil.

A typical cylindrically-seated BEARING is illustrated in part A of figure 3-17. The shell is lined with BABBITT METAL (a composition of tin, lead, and antimony), which is characterized by a tendency to quickly dispose of the friction heat by transferring it to the lubricating oil passing through the bearing. A dowel keeps the sleeve from turning. The BEARING CAP, or upper half of the bearing housing, is bolted securely to the lower half of the bearing housing. The bolts are not shown.



38.84X

Figure 3-17.—Turbine rotor bearings. A. Cylindrical bearing. B. Adjustable spherical-seated bearing.

The ADJUSTABLE SPHERICAL-SEATED SELF-ALIGNING BEARING (part B of fig. 3-17) is used in most modern main turbines. The shell assembly consists of upper and lower CYLINDRICAL SHELLS around which are fitted ADJUSTING KEYS or bushings with spherically shaped outer surfaces or seats. This male spherical seat fits into a similarly shaped female seat in the BEARING HOUSING—the spherical shape permits a small amount of shell movement to compensate for minor misalignments of the SHAFT. In some designs radial adjustment of the bearing is accomplished either by varying the thickness of the adjusting seats or by placing shims between the adjusting seats and the shells. In other designs adjustment is initially set at the factory and cannot be changed. This eliminates mis-adjustment in service. Since the bearings are located close to the shaft glands, OIL DEFLECTOR RINGS (part B of fig. 3-17) are fitted to the housing. This prevents leaking gland steam from contaminating the lubricating oil and also prevents the leakage of oil out of the bearing.

Thrust Bearings

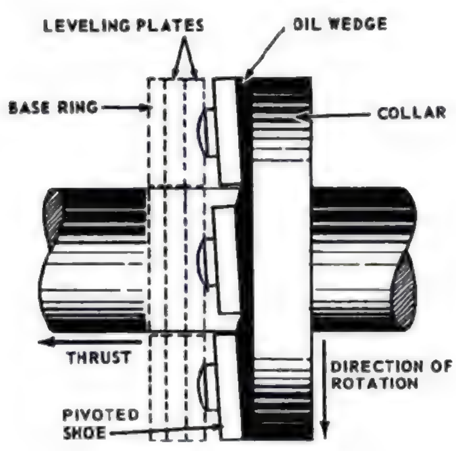
In addition to the radial bearings which serve to support and hold the rotor in correct radial position relative to the casing, a turbine is provided with an axial or thrust bearing. This thrust bearing limits the axial or fore-and-aft travel of the rotor and thereby maintains the necessary clearance between moving and stationary parts within the turbine.

In some auxiliary turbines, thrust bearings of the ball or roller type are used. In others, the radial bearing is designed to present a small axial bearing surface, as well as the radial bearing surface; this type of bearing is actually, therefore, a combination radial and thrust bearing.

In a small thrust bearing, the babbitt-faced thrust plate is rigidly attached to the bearing housing. To facilitate the entry of lubricating oil to the running surface, the babbitt-faced

surface is usually provided with radial grooves. This type of bearing works satisfactorily for light thrust loads and slow shaft speeds. But in a thrust bearing of a large, high-speed turbine or propeller shaft, a rigidly mounted thrust plate, even though grooved, would not maintain an adequate oil film between the thrust face of the bearing and the thrust face of the collar. To overcome this difficulty, main turbine and propeller shafts are equipped with a pivoted shoe (Kingsbury) type thrust bearing. In this type of bearing the thrust plate, instead of being a single, rigidly mounted, babbitt-faced piece, consists of a number of babbitt-faced segments or shoes that are free to assume a slight tilt. This freedom to assume a tilt aids in maintaining an adequate oil film between the shoe faces and the thrust collar.

The Kingsbury type thrust bearing shoes pivot on the upper leveling plates in such a way that they may be tilted very slightly (above 0.001 to 0.002 inches). Because the entire assembly is submerged in oil, the pivoting arrangement allows the formation of a continuous wedge-shaped oil film between the shoes and thrust collar (fig. 3-18). Whenever the shaft rotates, oil is dragged in (between the collar and each shoe) at the leading edge of the shoe which is beveled 30 degrees to allow the oil to enter. The thrust on the shaft or collar has a tendency to squeeze the oil out again. Since the oil streams in at the leading edge and goes out at the sides and at the trailing edge, the oil film under the leading edge of the shoe is thicker



38.86.1
Figure 3-18.—Diagrammatic arrangement of a Kingsbury thrust bearing, showing oil film.

than at the trailing edge. In other words, as long as the shaft is rotating, each of the shoes is riding on a wedgeshaped oil film.

Turbine thrust is usually in one direction only. Most Kingsbury type thrust bearings have shoes on both sides of the collar to take care of axial thrust in either direction. In some turbines, where the rotor thrust is always in one direction, or only very slight in the other direction, pivoted shoes may be used on the thrust absorbing side only; the non-thrust side may have three shoes, or a smaller diameter thrust bearing.

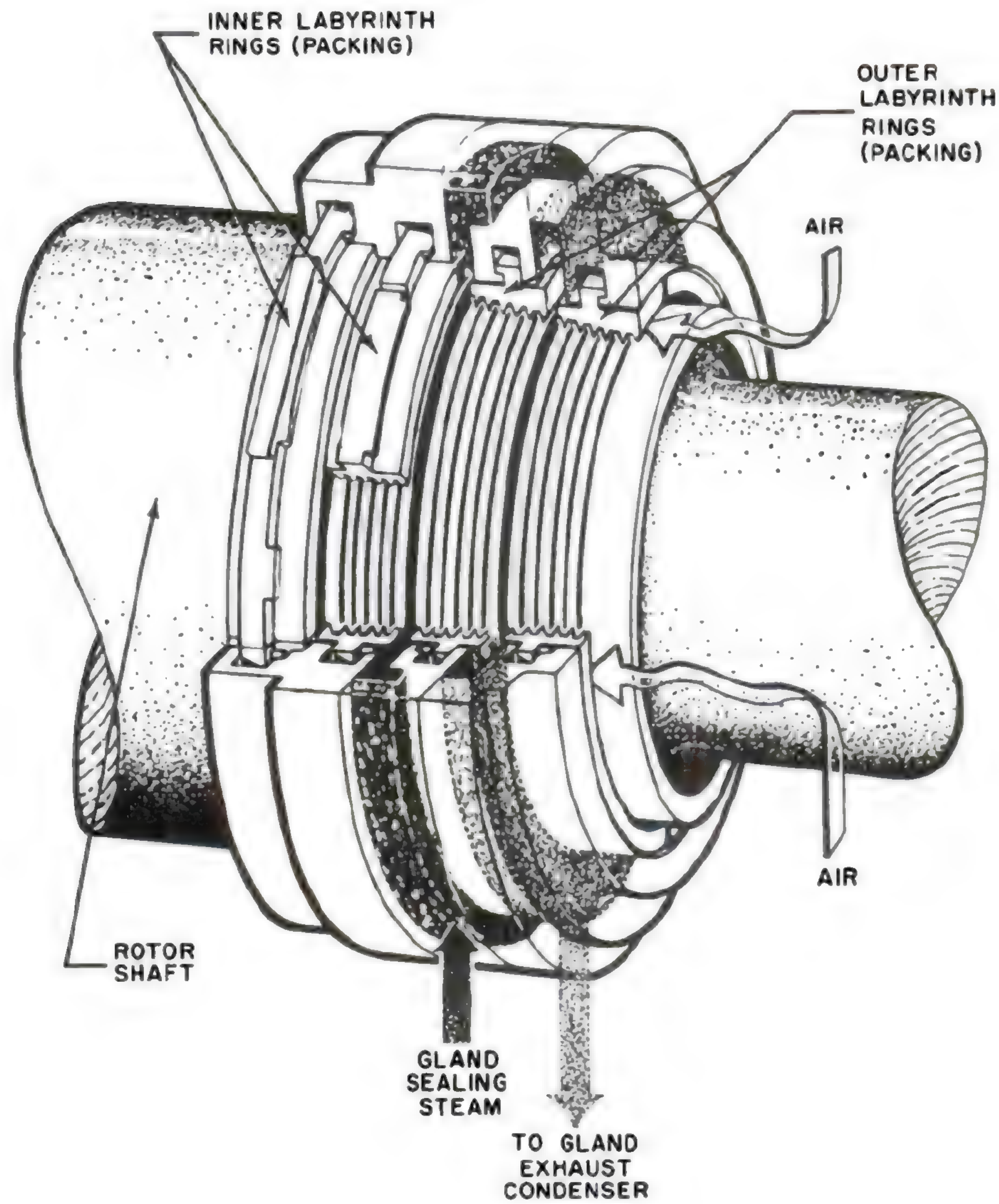
A thrust bearing may be installed in a separate housing, or it may be enclosed within the radial bearing housing. For details on construction and principles of operation of a Kingsbury thrust bearing, refer to chapter 4 of this training manual.

SHAFT PACKING GLANDS

When the pressure inside the turbine casing is greater than atmospheric pressure, shaft packing glands are used to prevent the escape of steam from the casing. The packing glands also prevent air from entering the turbine when the pressure within the casing drops below atmospheric pressure.

There are three types of shaft glands most generally used on naval turbine installations—labyrinth packing glands, carbon packing glands, and a combination of both labyrinth and carbon packing glands. Since labyrinth packing glands and carbon packing glands are discussed and illustrated in Fireman, NAVPERS 10520-D, the paragraph which follows deals with labyrinth packing gland because it is the most widely used turbine shaft seal in modern naval turbine installations.

LABYRINTH PACKINGS (fig. 3-19) are used in the gland and interstage of the modern steam turbines. Labyrinth packing consists of machined packing strips or fins mounted on the casing surrounding the shaft so as to make a very small clearance between the shaft and the strip. Figure 3-19 shows a labyrinth packing gland. The principle of labyrinth packing seals is that as steam leaks through the very narrow spaces between the packing strips and the shaft, its pressure drops. As the steam passes from one packing strip to the next, its pressure is gradually reduced and any velocity that it might gain through nozzling is lost by eddy motion.

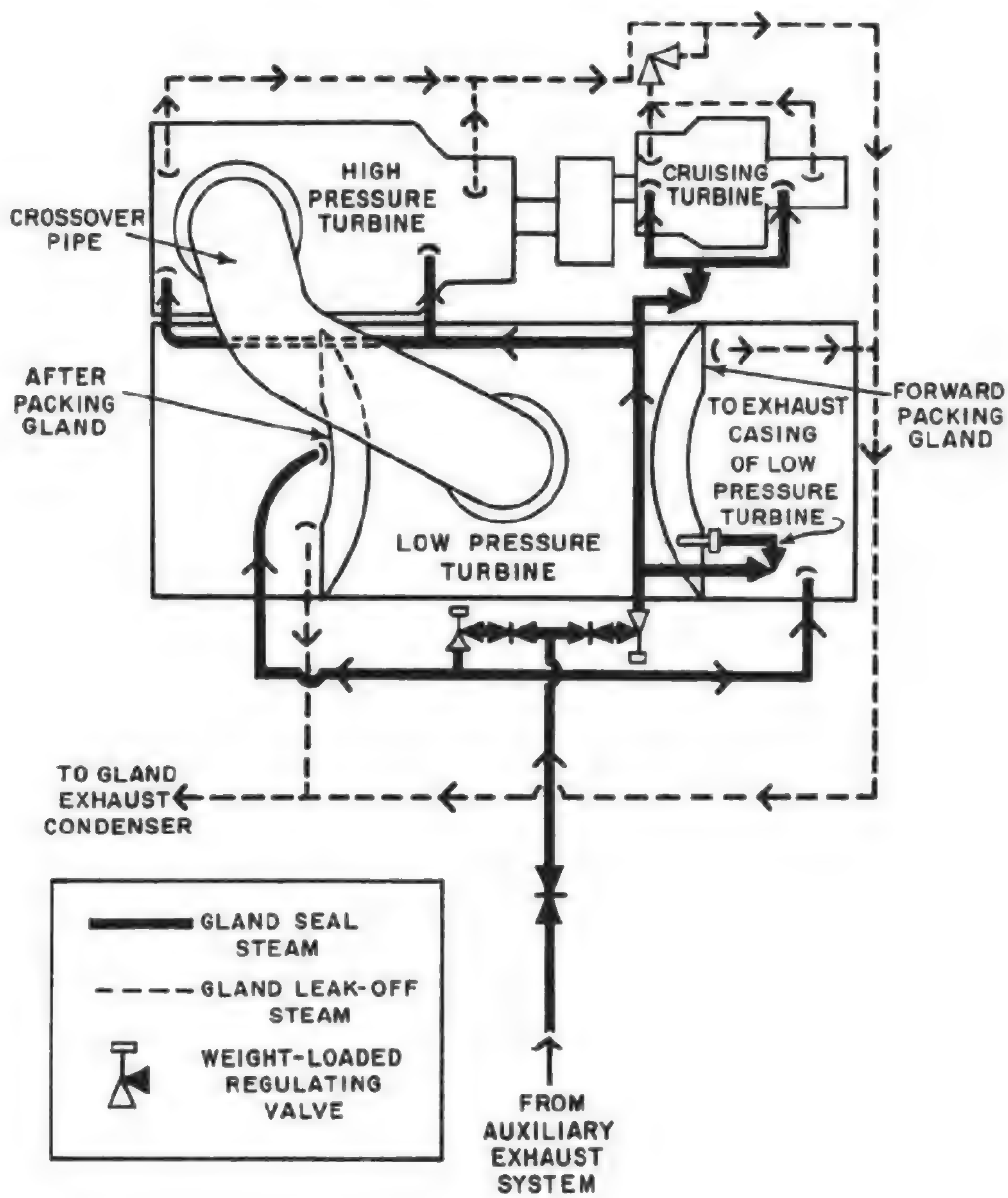


47.19(47D)
Figure 3-19.— High pressure turbine gland.

GLAND SEAL

Packing alone will neither stop the flow of steam out of the turbine nor prevent the flow of air into the turbine. Gland sealing steam is used to prevent the entrance of outside air into the turbine, which would reduce or destroy the vacuum in the main condenser. Figure 3-20 shows how gland sealing steam of about 2 psig (17 psi absolute) is led into a space between two sets of gland packing. On older ships, steam is supplied from the auxiliary exhaust steam line through a stop valve. Two weight-loaded valves operate automatically to maintain a pressure of 1/2 to 2 psig on the glands.

During periods of warming-up, low speed operation, backing-down, and securing, these weight-loaded valves are open. When the turbine



38.12

Figure 3-20.—Gland seal and gland exhaust system for propulsion turbines (destroyer).

is speeded up, and the steam flowing out of the labyrinth gland of the high pressure turbine reaches 2 psig, the valve supplying the high pressure turbine closes automatically—admitting no more gland steam from the auxiliary exhaust line. The high pressure turbine gland is then supplying enough steam leakage to seal the low pressure glands. As the turbine speed is still further increased, and the pressure in the sealing system rises to about 2 1/2 psig, the excess steam is led, by a manually operated or an automatically operated valve, either to the main condenser or to the low pressure turbine (depending on the ship).

The leak-off connections (fig. 3-20) are linked to the GLAND LEAK-OFF PIPING, which collects and condenses the steam that leaks from the gland, thus preventing the escape and loss of steam to the atmosphere.

A fan type GLAND SEAL EXHAUSTER (not shown) puts a slight vacuum on the leak-off piping. This vacuum draws the leak-off steam through a GLAND EXHAUST CONDENSER, where the steam is condensed and returned to the feed system.

On newer ships the gland sealing system is arranged differently. Steam is normally supplied from the 150 psi steam line. It is reduced to 2 psi through a diaphragm-operated control valve, actuated by an air pilot. The pilot is supplied with compressed air at 20 psi through a pressure reducing valve. A hydraulically actuated automatic regulator is also used on newer ships. It works in much the same way as the air actuated unit. This system also provides for the recovery of steam leaking from the main turbine valve stems and of excess sealing steam from the inner pockets of the high pressure turbine glands. For standby, astern, and slow ahead speeds, both glands on the high pressure turbine require sealing steam; while at all speeds, the glands on the low pressure turbine require sealing steam. At approximately 20 knots, the pressure in the high pressure turbine becomes high enough so that the forward gland no longer needs sealing steam. The excess steam is then led to a header and helps to seal the low pressure glands. Any excess steam is led to the main condenser by way of a relief valve. The gland exhaust system removes the air and steam mixture from the four turbine glands. Most of this mixture is condensed in the gland exhaust section of the main air ejector condenser and returns to the condensate system. The air and noncondensable gases are exhausted, by the gland exhauster, to the atmosphere.

Ship's service generator turbines are sealed in the same way, but they require an independent sealing system, so that they may be operated in port with the main plant secured.

TURBINE CONTROL UNITS

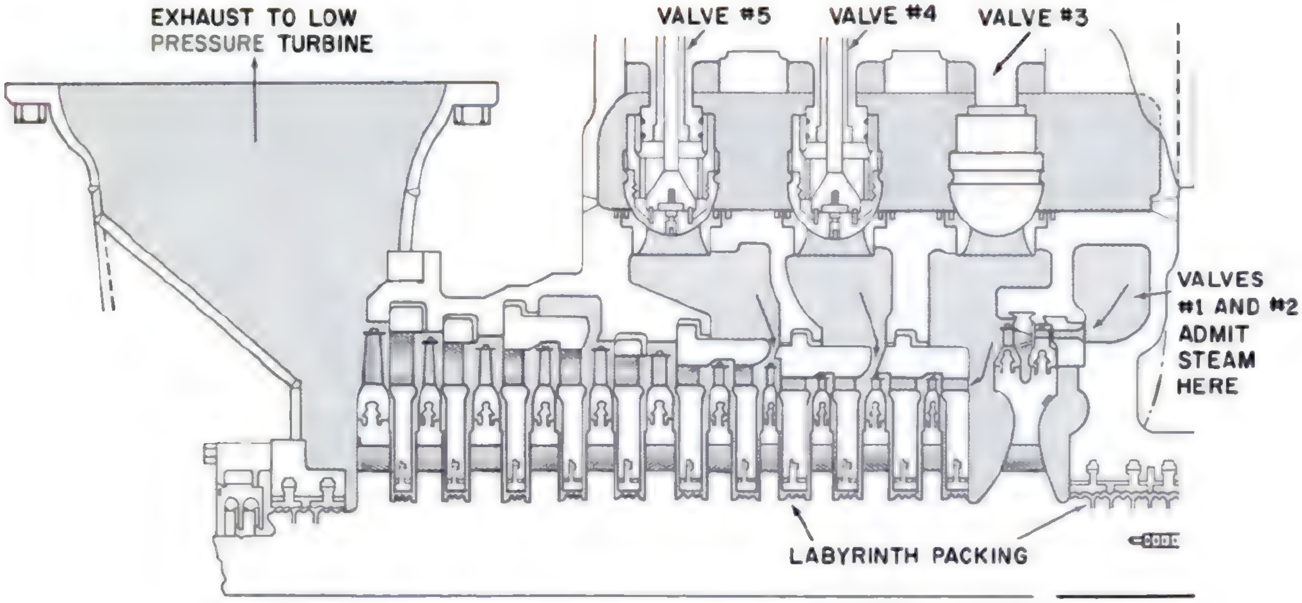
To start, stop, or reduce the steam flow to the main propulsion turbines, a system of cam-operated NOZZLE CONTROL VALVES is operated by a single handwheel. The amount of steam entering the high pressure or cruising turbine depends upon the degree to which the nozzle control valves are opened.

NOZZLE CONTROL VALVES

Since space limitations do not permit a detailed discussion of all ship types, the following description of a DD installation will serve to acquaint you with a typical turbine control system.

Three nozzle control valves admit steam to the cruising turbine via the cruising turbine chest. As speed is increased, operating gear (THROTTLE CONTROL VALVE) leading from the main gage board rotates a cam shaft which causes cams to lift three valves successively. There are five valves which admit steam to the high pressure turbine. These valves are cam-operated the same as those of the cruising turbine. The first two of these valves to open admit steam to the first-stage chest (fig. 3-21) of the turbine.

With valves #1 and #2 fully open, the steam pressure in the steam chest is approximately at line pressure. The first-stage nozzles are passing steam to the first stage at the limit of their capacity. To further increase the power and speed of the turbine, it is necessary to increase the amount of steam flowing through the turbine. To do this, valve #3 is opened. This admits steam from the chest through a bypass to the second-stage nozzles. The increased volume and velocity of the steam impinging upon the blading increase the turbine power and speed. With valve #3 wide open, it is necessary to open valve #4 to obtain a further increase in power. This admits steam from the chest through a by pass to the fourth-stage nozzles. With valve #4 wide open, the plant should operate at almost its full power rpm. Valve #5 will, when opened, admit steam to the sixth-stage



47.20

Figure 3-21.—High pressure turbine showing valve arrangement.

nozzles. This will permit operation of the turbine at its maximum available speed and power.

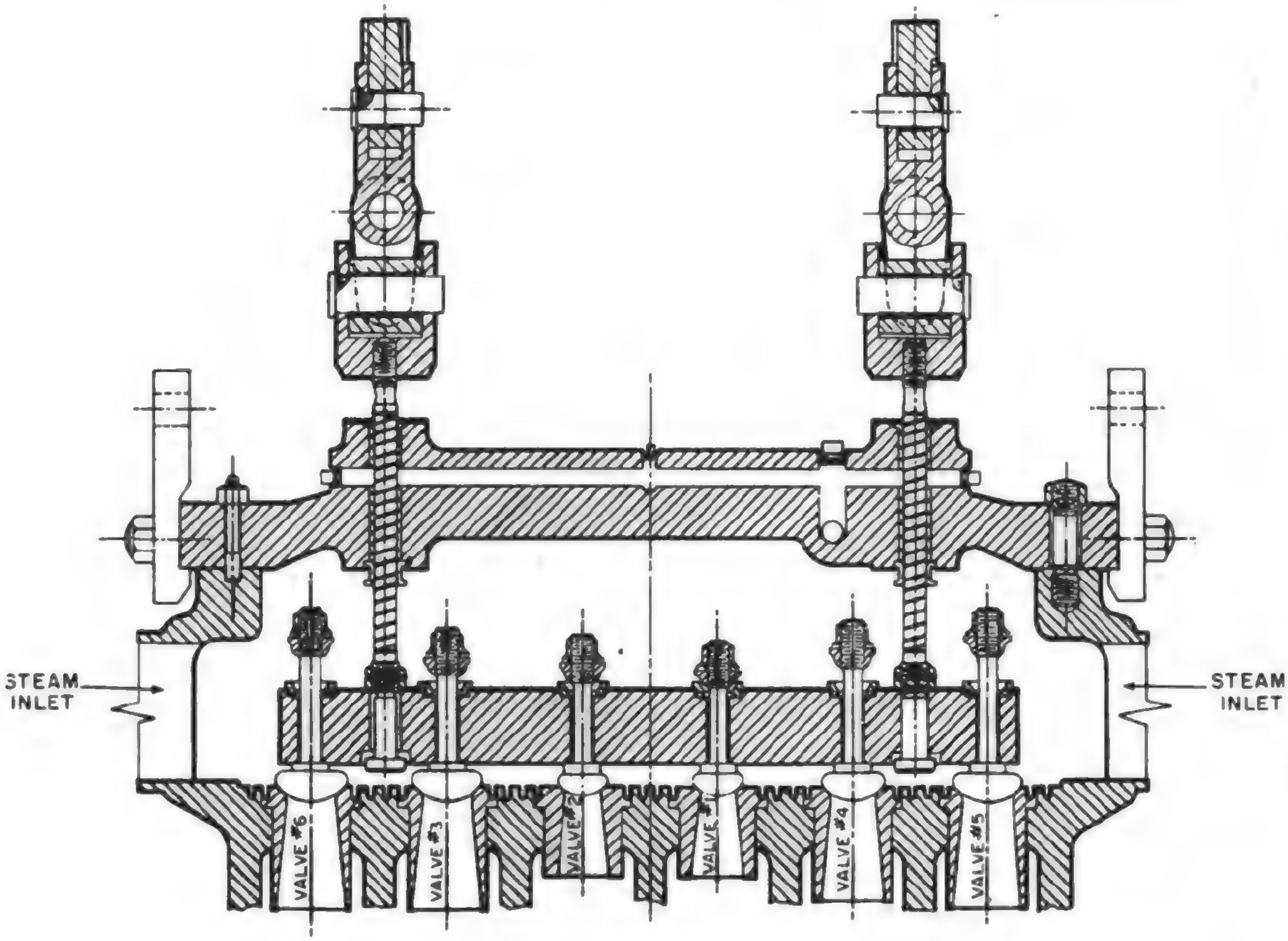
On the more modern ships, as the handwheel is rotated, an indicator on the throttle control valve mounting shows which valves are open. Valve #1 begins to open as soon as the indicator moves away from the SHUT position. The other valves open at the points indicated on the indicator as the handwheel is turned counterclockwise. When the indicator reaches the OPEN position, all valves are fully open. Turning the handwheel in the clockwise direction closes the valves in the reverse order in which they were opened.

On modern ships, the nozzle control valve arrangement shown in figure 3-22 is employed. The throttle valve is omitted and steam enters the turbine through nozzle control valves. Speed control is effected by varying the number of nozzle valves that are opened. The variation in the number of nozzle valves is accomplished through the operation of a lifting beam mechanism. The lifting beam mechanism consists of a steel beam drilled with holes which fit over the nozzle valve stems. The valve stems are of varying lengths and are fitted with shoulders at the upper ends. When the beam is lowered, all valves rest upon their seats. When the beam is raised, the valves open in succession, depending upon their stem length—the shorter ones open first, then the longer ones.

CRUISING ARRANGEMENTS

Every ship has a speed at which the fuel consumption per mile is at a minimum. The most economical speed is based upon the combined fuel consumption per mile of the propulsion engines and the auxiliary machinery. However, a considerable quantity of fuel is required by the auxiliary machinery, even when the ship is stopped; as the speed is increased, there is only a very gradual increase in the amount of fuel consumed (per hour) by the auxiliary machinery. Therefore, as the ship's speed is increased, the fuel consumed (per mile) by the auxiliary machinery actually decreases. These varying rates of fuel consumption for the auxiliary machinery result in a most economical speed, for turbine-driven ships, of between 12 and 20 knots, depending upon the type of ship.

In order to conserve fuel and thereby increase the ship's cruising radius, a major part of all steaming is done close to the most economical speed; therefore, the most economical speed is generally designated as cruising speed. Although it is desirable to have the most economical speed as high as possible, there is a



147.96
Figure 3-22.—Arrangement of nozzle control valves.

practical limit above which this speed cannot be raised (because of the progressively increasing resistance of water to the ship's hull as the speed of the ship is increased). Increasing the efficiency of the main engines will tend to raise the most economical speed. The propulsion turbines are designed to have their best steam rate at the cruising speed.

It is also desirable for combatant ships to be able to steam at or near full power for long periods of time. This requirement makes it necessary for propulsion plants to be designed with a relatively high turbine efficiency at high speeds.

Maximum efficiency in a turbine is obtained when the optimum ratio of blade speed to steam speed exists. Therefore, in order to obtain the lowest possible fuel consumption per mile at cruising speed and at full power, it is necessary that propulsion turbines be designed so that the optimum ratio of blade speed to steam speed will be approached at both these speeds. This is accomplished by the use of (1) cruising stages and in older ships (2) cruising turbines.

Cruising Stages

In order to attain the optimum ratio of blade speed to steam speed at or near cruising speed, high pressure turbines are designed so that in the first few stages there are relatively small blades which have a large pitch diameter. These stages, usually velocity-compounded, are known as cruising stages. Cruising stages may be defined as those stages, incorporated into the high pressure end of a high pressure turbine, which provide for the optimum ratio, at or

near cruising speed, of blade speed to steam speed.

The small blades in the cruising stages restrict the quantity of steam which can be passed, with a given steam line pressure, through the turbine. Thus, while they increase the turbine efficiency at or near cruising speed, the small blades limit the steam flow and, therefore, the power which the turbine can develop. In order to permit a larger amount of steam to pass through the turbine, bypasses (fig. 3-23) are installed. (These bypass valves allow the steam to be bypassed around the cruising stages when high power is desired. The bypasses allow high pressure steam to work directly on the larger blades of the later stages, thereby developing more power.)

Cruising Turbines

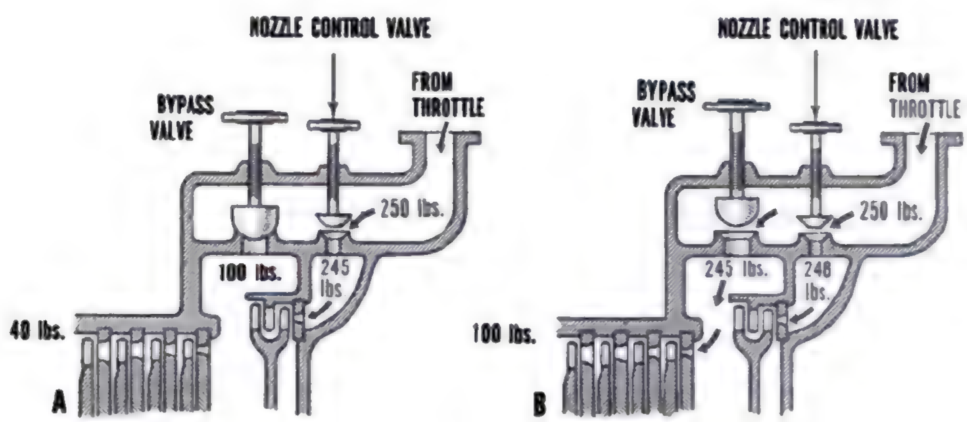
In some installations, the optimum ratio of blade speed to steam speed at cruising speeds is attained by means of a separate, small turbine, known as a cruising turbine. These turbines are similar in design to high pressure turbines, except that they are smaller in size and are not fitted with bypasses. When a cruising turbine is in use, steam passes through the cruising turbine before it goes to the high-pressure turbine. In this way, the steam is expanded through a greater number of pressure stages and more energy is extracted from the steam than would be possible by the use of the high pressure and low pressure turbines. When speeds in excess of the cruising turbine's range are desired or anticipated, the steam is led directly to the high pressure turbine, bypassing the cruising turbine. When cruising turbines are bypassed, cooling steam is supplied to the cruising turbine by means of a crossover valve, installed on the cruising turbine exhaust, between the cruising turbine and the high pressure turbine. Because of their high speed of rotation, cruising turbines are connected to the high pressure turbine shaft through a reduction gear and shafting.

AUXILIARY TURBINE GOVERNORS

You have studied the various types of main propulsion and auxiliary turbines and how they work; and how the cam-operated nozzle control valves regulate the amount of steam entering a high pressure or cruising turbine, thereby controlling turbine speed. However, in auxiliary turbines used to drive generators, forced-draft blowers, pumps, air compressors, and other auxiliary machinery, some speed controlling governor or device must be used.

Types of Governors

Generally speaking there are two types of governors in use: constant speed governors and speed limiting governors. The CONSTANT SPEED GOVERNOR is used on constant speed machines to maintain a constant speed regardless of the load on the turbine up to design limits. Constant speed governors are usually set so that



47.13A

Figure 3-23. — Diagrammatic arrangements of a bypass valve. A. With valve closed. B. With valve open.

the turbine cannot even momentarily exceed 100 percent of normal operating speed. Their primary use is on turbine-generator units.

The SPEED LIMITING GOVERNOR, used principally on variable speed machines, allows a turbine to operate under all conditions from no-load to over-load, up to the speed for which the governor is set, but it does not allow operation in excess of 115 percent of normal operating speed. Since this type of governor is adjusted to the maximum operating speed of the turbine, it has no control over the admission of steam until the upper limit of safe operating speed is reached.

Ship's service generators supply electricity for lighting and power throughout a ship. Since a constant voltage must be maintained on ship's service lines, the generator turbine operates, even under greatly varying loads, at a constant speed. This speed is maintained by means of a constant speed governor.

A typical ship's service generator turbine control mechanism (fig. 3-24) consists of a centrifugal governor which operates a pilot valve controlling the flow of oil to an operating cylinder. The latter, in turn, controls the amount of opening or closing of the turbine nozzle valves.

A gear-type oil pump and the main governor, mounted on the same shaft, are driven through a worm and gear (fig. 3-24). The worm is directly connected to the low speed gear shaft of the turbine reduction gear and thereby drives the governor at a speed that is directly proportional to the turbine speed.

On some installations, the turbine nozzle valves are operated by a lifting beam. The nozzle valve stems, of varying lengths, are designed so that they slide freely through holes in the lifting beam. As the beam is moved up and down, the nozzle valves open and close in a predetermined sequence.

Governor Operation

When a governor tends to slow down, because of an increased load on the generator, the governor weights move inward and cause the pilot valve to move upward. This permits oil to enter the operating cylinder. Thus, the operating piston rises and, through the controlling-valve lever, the lifting beam is raised. The nozzle valves open and admit additional steam to the turbine. This upward motion of the controlling-valve lever causes the governor lever to rise, thus raising the bushing. Upward motion of the bushing tends to close the upper port, shutting off the oil flow to the operating cylinder; this stops the upward motion of the operating piston. The purpose of this follow-up motion of the bushing is to regulate the governing action of the pilot valve. Without this feature the pilot valve would operate, with each slight variation in turbine speed, to alternately fully open and fully close the nozzle valves.

When the turbine tends to speed up because of a decreased load on the generator, the governor weights move outward, moving the pilot valve downward, opening the lower ports, and allowing oil to flow out of the operating cylinder. This action causes the controlling-valve lever to lower the lifting beam, thereby reducing the amount of steam delivered to the turbine. The downward motion of the controlling-valve lever causes the governor lever to lower; this lowers the bushing. The downward motion of the bushing tends to close the lower port, preventing oil from flowing out of the operating cylinder.

SAFETY DEVICES

All turbogenerators have four safety devices: an overspeed trip, a back-pressure trip, a low-oil pressure trip or alarm, and an emergency hand trip.

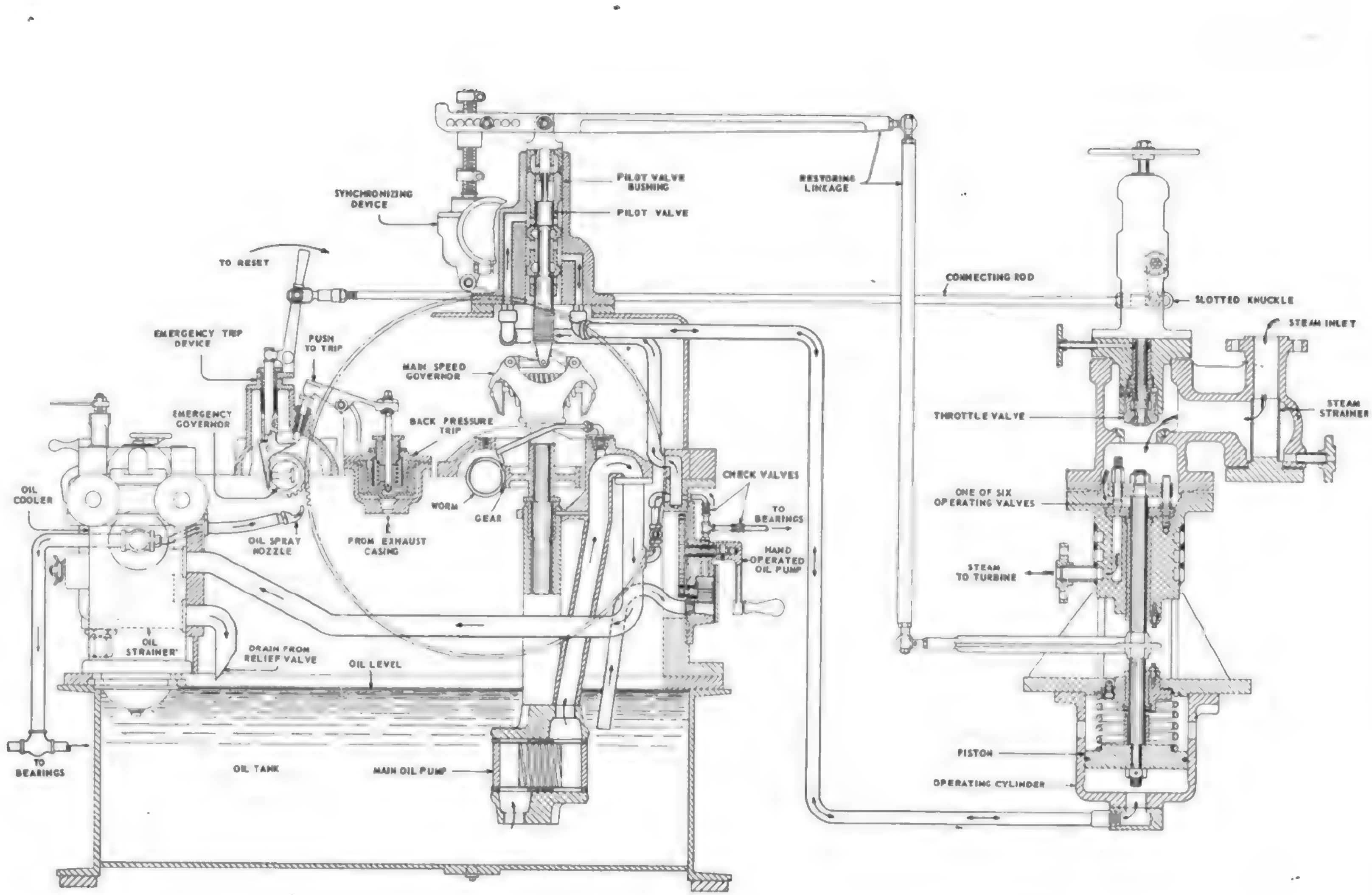
Safety devices differ from control devices in that they have no control over the turbine under normal operating conditions. It is only during some abnormal condition that safety devices come into use — to either stop the unit or control its speed.

The OVERSPEED TRIP shuts off the steam supply to the turbine after a predetermined speed has been reached, and thus stops the unit. Overspeed trips are set to trip out at about 110 percent of normal operating speed.

The BACK-PRESSURE TRIP is used to close the throttle automatically whenever the back or exhaust pressure reaches a set pressure.

The LOW-OIL-PRESSURE TRIP is used on turbogenerators to close the throttle if the lubricating oil pressure drops below a specified pressure.

The EMERGENCY HAND TRIP is fitted to all turbogenerators to provide for closing the throttle quickly, by hand, in case of damage to either the turbines or generator. The emergency hand trip may also be used to close the throttle valve when the turbogenerator is secured.



47.21
Figure 3-24. — Ship's service turbine-driven generator governor system.

STEAM-DRIVEN TURBOGENERATORS AND TURBOGENERATOR OPERATION

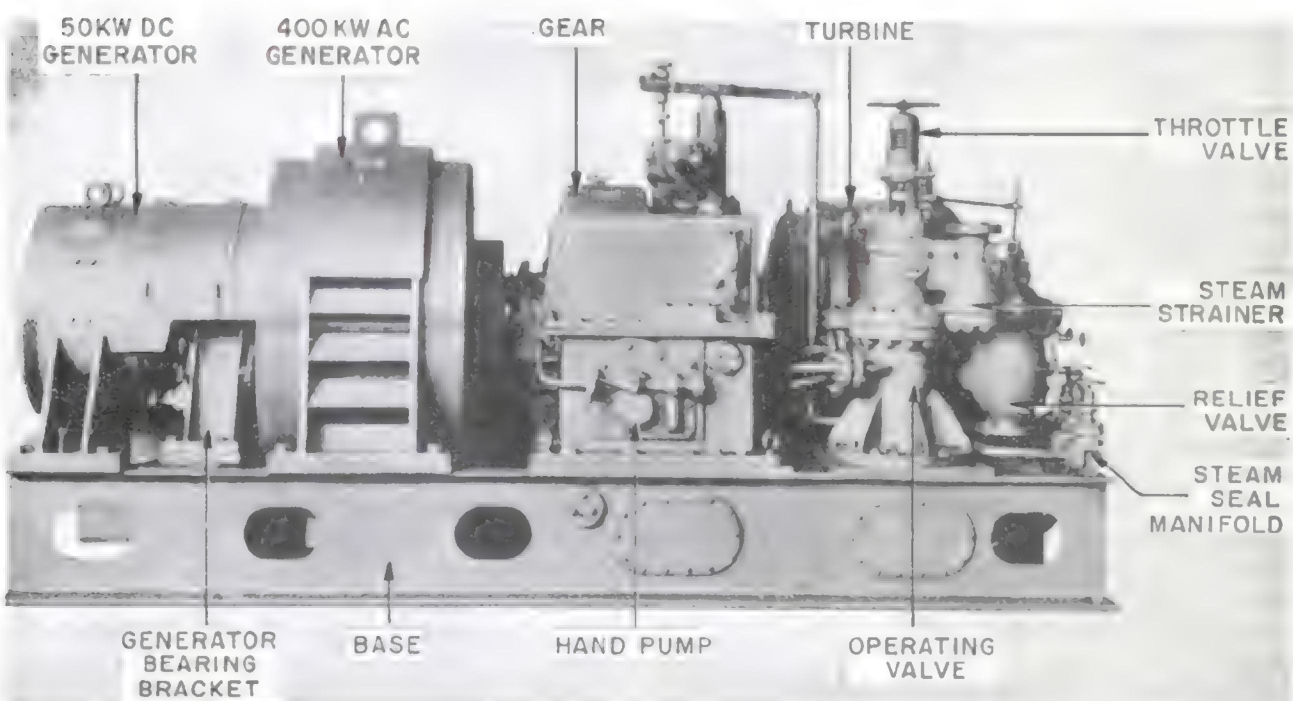
Electrical power provided by steam-driven turbogenerators, is a vital part of today's modern Navy. Many factors such as maximum power requirements, safety, and reliability determine the number of generators installed aboard each class of ship. A DD-692 class destroyer has two steam-driven turbogenerator sets (turbogenerators) and two diesel-driven emergency generators. A modern CVA, however, has eight steam turbogenerators for ship's service, three diesel-driven emergency generators, and two steam turbine-driven, 400-cycle generators for I.C. circuits, fire control circuits, and aircraft starting.

There are three types of turbogenerators employed within the Navy, as follows:

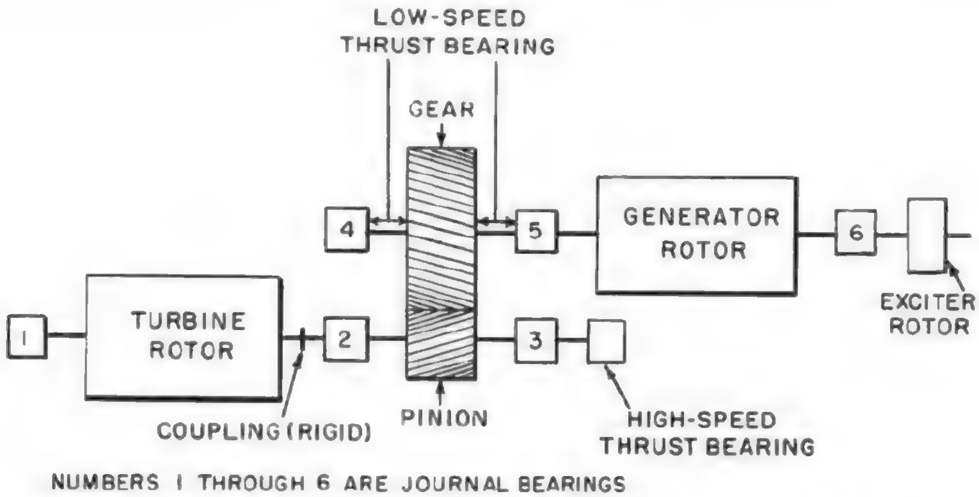
TYPE I — Condensing, constant speed operation
TYPE II — Noncondensing, variable speed operation
TYPE III — Condensing, constant and variable speed operation.

Type I is the most prevalent installation aboard naval ships. Therefore, the discussion which follows is confined to the Type I turbogenerator installation.

The general arrangement of turbogenerators on all surface ships is very similar. Figure 3-25 shows a typical turbogenerator for a small ship. The turbine and pinion shafts are rigidly connected and supported by three bearings, as shown in figure 3-26. Bearings numbers 2 and 3 are in the reduction gear casing and support the pinion shaft and the gear end of the turbine shaft. Bearing number 1 supports the opposite end of the turbine shaft. The high speed thrust bearing is located on the generator end of the pinion shaft, outside the gear casing. The location of the thrust bearing varies on new construction units but is located predominately at the steam-inlet end of the turbine. Bearings numbers 4 and 5 (fig. 3-26) support the reduction gear and also are part of the slow speed thrust bearing; the faces of these bearings are babbitted and bear against thrust surfaces which are machined on the hubs of the gear. The babbitted bearing faces and the thrust surfaces of the gear hub form the slow speed thrust bearing. Bearing



96.17
Figure 3-25. — A turbine-driven generator.



96.18
Figure 3-26.—Positions of bearings in a turbogenerator.

number 6 (fig. 3-26) supports the generator and exciter rotor. The exciter rotor is eliminated on modern turbogenerators that employ static excitation.

Steam enters the turbine through a steam strainer, passes through the throttle valve, then through the controlling valves, and then to the first stage nozzles. The steam then passes through the turbine stages (usually 5 to 10), from initial pressure to final or condensing pressure.

The speed of the unit is controlled by a constant speed governor which is of the centrifugal type. The governor speed setting can be adjusted electrically or manually to control the speed of the turbine.

The throttle valve is provided with a handwheel for manual control and for resetting the valve after it has been tripped. The throttle valve closes when the overspeed trip or high back pressure trip functions, or when the manual trip lever is pushed.

Most submarines use a direct drive turbogenerator which usually has a flexible coupling installed between the turbine and the generator. Direct drive turbogenerators are used on submarines for ship's service because the inlet steam conditions are relatively low and therefore the available energy of the steam to the turbine is low compared with surface ships. This permits the turbine to operate at low speeds and still maintain a satisfactory efficiency. The elimination of the reduction gears considerably reduces the noise level of the turbogenerator.

Surface ships use direct drive turbogenerators to produce 400-cycle power for IC and control circuits and aircraft starting. High speed generators are necessary in order to generate 400-cycle power; therefore, both the generator and the turbine can run at high speeds (normally 12,000 rpm) and thus maintain high turbine efficiency.

The auxiliary air ejectors maintain a vacuum in the auxiliary condenser. They are basically the same as main air ejectors. In order to provide continuous plant operation, two sets of nozzles and diffusers are provided for each air ejector condenser. Only one set is necessary for normal operation of the plant; the other set is for use in case of damage or malfunctioning of the set in use. Both sets may be used when there is excessive air leakage into the auxiliary condenser. On some installations, the second air ejector set has a higher capacity and is used in starting the plant. After the normal condenser vacuum has been established, the smaller set should be started and the larger set secured.

The auxiliary circulating pump is a high capacity, low pressure, centrifugal, motor-driven pump. The pump has separate injection and overboard valves. Some auxiliary circulating pumps supply cooling water to the turbogenerator lube oil cooler. In some installations, cooling water for the auxiliary condenser can be taken from the firemain, in case of failure of the circulating pump.

The auxiliary feed booster pump is a centrifugal, motor-driven pump used to maintain

a pressure on the suction line to the emergency feed pump during in-port operation. In case of failure of this pump, a main feed booster pump may be used as a part of the auxiliary plant.

STARTING A TURBOGENERATOR

When a turbogenerator is started, it is subject to expansion due to the temperature change it will undergo. When a turbine is going to be placed in service, a reasonable amount of time should be spent in warming it up, gradually increasing the speed until it is ready for full load.

When starting a turbine driving a generator, the following procedure is recommended:

1. Be sure that the unit is free of all loose material and that all working parts are clean and well oiled.
2. Test the manual trip to ensure that it is functioning properly.
3. Check the level and temperature of oil in the sump tank. The oil level should be at the maximum mark on the gage and the temperature of the oil should be above 60°F.
4. Open the drain ahead of the throttle valve. Leave the drain open until all water is drained out of the line and dry steam is being discharged.
5. Open the root valve slowly so as to warm the line gradually, and drain the water from it.
6. Open the turbine exhaust valve.
7. Open the injection and overboard valves, start the auxiliary circulating pump, and make sure that water is being circulated through the condenser.
8. Start the auxiliary condensate pump. Open the recirculating valve to ensure an adequate amount of cooling water for the auxiliary air ejector condenser.
9. Drain the air ejector steam line and cut steam into the auxiliary air ejectors. Bring the vacuum up to about 15 inches.
10. Start turning the hand oil pump. Keep the hand oil pump turning until the unit has been started and the attached oil pump takes over. Check the oil pressure gages and sight-flow indicators to ensure an oil flow to the bearings.
11. After the controlling valve has been lifted by the oil pressure, open the throttle valve sufficiently to start the turbine rolling. Under no circumstances shall steam be admitted to the turbine, for any appreciable length of time, with the rotor stationary. Uneven heating will distort the rotor and cause vibration when the turbine is started.
12. After the turbine has started, test the manual trip to see that it operates properly.
13. Reset the trip and open the throttle valve just enough to keep the unit turning.
14. Admit steam to the packing glands and bring the vacuum up as far as possible.
15. Slowly bring the unit up to about half speed and operate the unit at that speed for several minutes. The length of this warming-up period may vary with different installations, details may be found in the manufacturer's technical manual.
16. During the warming-up period, watch all bearing oil temperatures, listen for any unusual noises, and check for vibration. If a rubbing noise is detected, decrease the speed of the unit until the noise disappears; or if the noise continues, secure the unit and locate and correct the trouble.
17. When the temperature of the oil reaches 100°F, open the inlet and outlet water valves on the lube oil cooler. Regulate the temperature of the oil by closing down or opening up on the cooling water outlet valve.
18. When the unit is properly warmed up, open the throttle valve until the constant speed governor takes control.
19. Increase the speed until the overspeed trip functions. Close the throttle valve, reset the overspeed trip, and gradually bring the speed of the unit up to operating speed.

When bringing a generator turbine up to speed, you should always accelerate rapidly through the critical speed of the unit. The slight vibration which may occur when going through critical speed will disappear when the unit is up to operating speed. The critical speed of a generator turbine usually is 20 to 25 percent below normal operating speed; for other auxiliary turbines, critical speed is well above operating range.

When the unit is operating normally, open the throttle valve wide; then close the valve about 1/2 turn to prevent the throttle sticking as the metal expands due to temperature increase.

The bearings are designed to ensure proper flow of oil when the oil enters the bearing at normal operating temperature. If the temperature of the oil is far enough below normal operating range, the flow of oil may be reduced to a point where it will not be sufficient to carry away the heat of the bearing. Low starting speeds

are, therefore, necessary when oil temperatures are low.

Turbogenerators should never be started until the oil in the sump is at least 60°F. Oil below this temperature can be heated by circulating it through the purifier heater, then the unit can be started and operated slowly until the oil entering the bearings is 100°F.

The oil level in the sump should be at the maximum mark on the gage to allow for the drop in oil level due to oil filling the system. On most installations, the generator oil cooler is fitted with a bypass. The oil flow can be diverted around the cooler until the oil temperature reaches approximately 100°F.

To prevent water hammer when warming up the turbogenerator steam line, open the drain ahead of the throttle valve. Do not open the throttle until all condensate is discharged from the line and the drain is discharging dry steam.

OPERATING A TURBOGENERATOR

When the unit is up to speed and the load is applied, the following steps should be observed during operation:

1. See that the oil cooler is receiving an adequate supply of cooling water. If the supply of water is insufficient, the bearings will overheat in a very few minutes.
2. See that the surface cooler is receiving cooling water, or that air is circulating through the generator, whichever is applicable.
3. Adjust the gland sealing steam in accordance with the manufacturer's instructions.
4. See that the oil pump delivers an adequate supply of oil to the bearings. If the oil cooler was bypassed during warming up, ensure that the bypass is closed during normal operation.

Periodically determine the temperature of the oil leaving the bearings. A satisfactory running temperature of the return oil is 140°F to 160°F. The maximum oil temperature should not exceed 185°F. The temperature rise of oil passing through any bearing should not exceed 55°F.

During operation, continuous attention should be given to the following:

1. Cleanliness of the unit.
2. Prevention of leakage of steam, oil or water.
3. Smoothness of operation and freedom from unusual noises or vibration.
4. Correct readings of pressure and vacuum gages.
5. Freedom of movement of the governor parts.

Make sure that all control and safety devices are in proper operating condition. If they are not, the unit should be stopped and the trouble located and corrected before the unit is again started.

SECURING A TURBOGENERATOR

When securing a turbogenerator, the procedure is as follows:

1. After the Electrician's Mates have shifted the electrical load to another generator, trip the throttle valve by pushing the manual trip button at the emergency tripping device.
2. Close the stop valve ahead of the throttle valve and open the drain ahead of the throttle valve.
3. Station a man at the hand lube oil pump, when the lube oil pressure (to the bearings) drops to about 5 psig, start turning the hand oil pump to maintain adequate lube pressure to the bearings and gears.
4. Secure the gland sealing steam.
5. Operate the air ejectors for several minutes to draw out all vapor from the turbine in order to prevent internal corrosion.
6. Secure the auxiliary air ejectors, auxiliary condensate pump, and the auxiliary circulating pump.
7. Close the inlet and outlet cooling water valves to the lube oil cooler.

When the unit is to be secured, even for a short time, take every precaution against steam entering the turbine casing. If the unit is to be restarted, bring it up to speed with the same care used when starting cold.

On older ships, turbogenerator operation can vary greatly. While each generator has its own auxiliary condenser to receive the turbine exhaust, some generator turbines can exhaust to the main condenser when the ship is underway and some can exhaust to the atmosphere. On more recently constructed naval surface ships, generator operation is similar, but each generator turbine exhausts only to its own auxiliary condenser except in most submarines, where the turbine exhausts only to the main condenser.

The operation of an auxiliary plant for a turbine-driven generator is explained in the following paragraphs.

The auxiliary plant is basically a small main plant. It consists of an auxiliary condenser, an auxiliary circulating pump, an auxiliary condensate pump, auxiliary air ejectors, and an auxiliary feed booster pump. It uses the main plant deaerating feed tank instead of having an auxiliary deaerating feed tank. The operation of each of these units is the same as the operation of the main plant, except that their capacity is far less.

An auxiliary circulating pump circulates sea water through the auxiliary condenser continuously during operation, instead of a scoop injection as in some main plants. The cooling water makes one or two passes through the condenser, the inlet water box on the two pass condenser being divided by a partition into an inlet chamber and outlet chamber.

The auxiliary condensate pump removes the condensate from the auxiliary condenser, discharges it through the auxiliary air ejectors, and into the deaerating feed tank. Auxiliary condensate pumps are small motor-driven centrifugal pumps with a capacity equal to the maximum condensing capacity of the auxiliary condenser. A recirculating line is fitted at the condensate outlet of the air ejector condenser and leads to the auxiliary condenser. When starting up and at low loads, the recirculating valve must be opened to prevent the condenser from being pumped dry. The recirculating line also ensures that sufficient cooling water will at all times be supplied to the air ejector condenser.

TURBINE MAINTENANCE

The maintenance of turbine installations is as important as their proper operation. If proper maintenance procedures are followed, abnormal conditions may be prevented. You will be concerned with major adjustments, as well as measurements, of turbines. In addition, you must know how to fit carbon packing rings to turbines.

MAJOR ADJUSTMENTS OF A TURBINE

In all propulsion turbines installed on ships in the Navy, there are two major adjustments: the fixing of the proper radial and axial positions of the rotor. The radial position of the rotor is maintained by the journal bearings, and the axial position by the thrust bearings.

In impulse staging, the radial clearances are large and have no effect on the efficiency of the turbine. The axial clearances also, within the limits permitted by the design of the turbine, will have almost no appreciable effect on the turbine efficiency, because the same pressure exists on both sides of the moving blades; as a result, there is no tendency for the steam to bypass the blades. In impulse staging, axial clearances are kept small in order to reduce the length of the rotor and the casing.

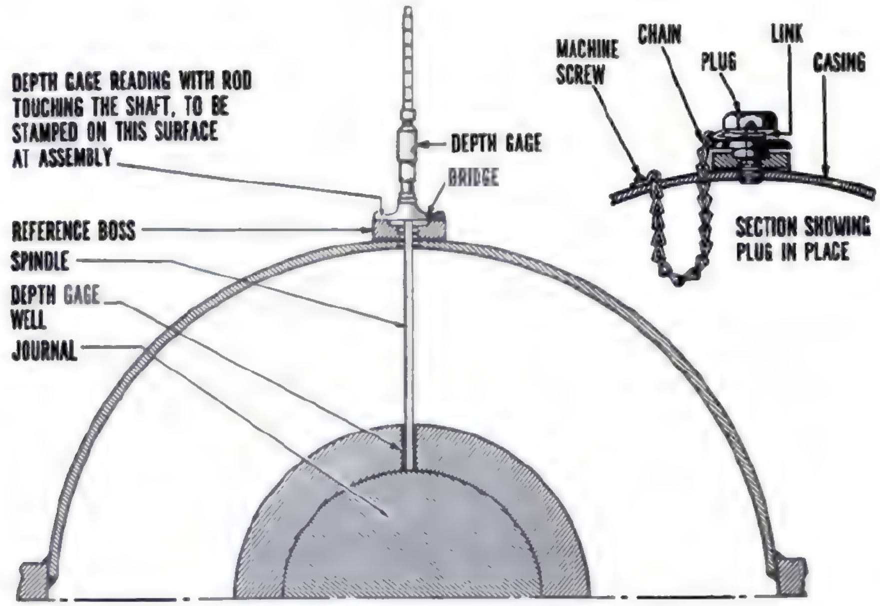
The clearances in all shaft and diaphragm packings are small, and they will be altered if the position of the rotor changes (as a result of wear, either of the journal or of the thrust bearings). This change results in reduced efficiency of the turbine because of the steam leakage from the glands, and repairs will eventually be necessary.

The major reason for maintaining a turbine rotor in its proper position is to prevent damage to the turbine. If the rotor touches the casing at any time, because of failure of the thrust or journal bearings, while the turbine is in operation, damage will result and it will be necessary to lift the turbine casing for repairs. The turbine parts that are particularly subject to damage, because of close clearances involved, are the rotor blading, diaphragm packing rings, shaft packing rings, and oil deflector or oil seal rings.

Radial Position of the Rotor

The quickest means of detecting any change in the radial position of the rotor, resulting from bearing wear, is by using the depth gage micrometer. When the turbines were installed originally, depth gage readings were taken and recorded. Any difference between the original and the new readings will be the amount of bearing wear in the lower half. For additional information on the use of micrometers refer to Tools and Their Uses, NAVPERS 10085-B.

To take new readings (fig. 3-27) a depth gage spindle is inserted into the depth gage well until the bridge of the gage rests evenly on the reference boss; the knurled handle of the micrometer is then turned until the spindle touches the journal. Read the micrometer and compare the new and the original readings.



47.22
Figure 3-27.— Bearing wear micrometer depth gage.

Another means of checking bearing wear is by measuring the crown thickness with a ball attached outside micrometer. When the turbine bearings were installed originally, the radial position of the turbine rotor was set, and by using a micrometer the combined thickness of the bearing shells and liners (at designated places) was measured and stamped on the bearing shell. To take new readings, the bearing cap must be removed, the top half of the bearing lifted off, and the lower half of the bearing rolled out. Radial lines are scribed on one end of each bearing to indicate the measurement points which are always 1 1/4 inches from the end of the bearing. Any difference between the shipboard and the factory measurements will be the amount of bearing wear.

Another way of measuring bearing wear is by using an inside micrometer to measure the inside diameter of the bearing and an outside micrometer to measure the outside diameter of the journal. The difference between the readings will be the oil clearance. The difference between the old and the new oil clearances will be the amount of bearing wear.

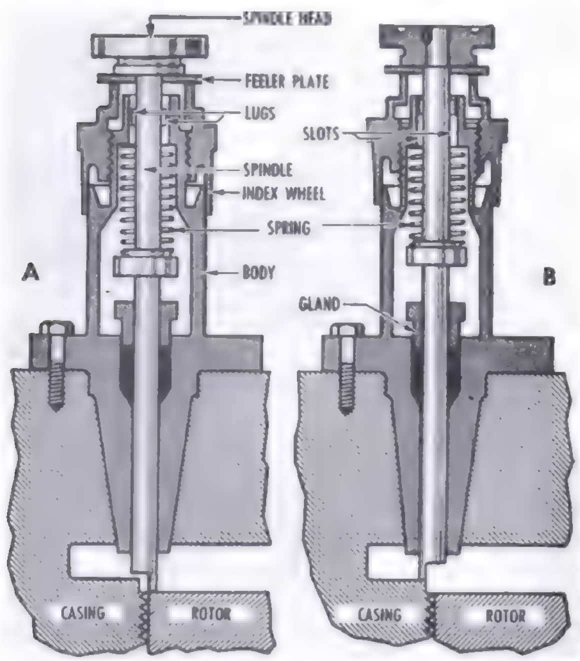
Axial Position of the Rotor

The axial position of a turbine rotor is maintained by means of a thrust bearing, usually of the pivoted segmental or Kingsbury type. With this type bearing, the axial position of the rotor is adjusted by machining from the filler piece, by adding shims, or by installing larger filler pieces.

The axial clearance instruments consist of the rotor position indicator and the relative rotor position indicator. The rotor position indicator is shown in figure 3-28. It is used on old type turbines, while they are in operation, to determine the axial position of the rotor and the amount of thrust bearing wear.

The principal parts of the rotor position indicator are: (1) the spindle, with spindle head attached; (2) the body, attached directly to the turbine casing; (3) the index wheel, which is threaded to the body and graduated to read axial movement in thousandths of an inch; (4) the feeler plate; and (5) the spring. The spindle is cut away at the end, leaving only a half-section.

With the spindle turned as shown in part A of figure 3-28, the protruding half-section rests against the turbine rotor; when it is turned 180°, as shown in part B of figure 3-28, it rests against a projection of the casing. The spindle is kept from turning, when not pulled all the way out, by means of two projecting lugs (on the spindle), a short distance from the spindle



47.23X
Figure 3-28. — Rotor position micrometer.

head. These lugs slide in slots machined on the inner diameter of the body. When the spindle is not resting against the casing or rotor, the feeler plate is held tightly between the index wheel and the spindle head by the compression of the spring. However, when the index wheel is advanced until the spindle touches the casing or rotor, the spindle head and index wheel separate and allow the feeler plate to become free. The purpose of the feeler plate and spring arrangement is to enable the operator to know when the spindle is just touching the rotor or casing. In addition, the danger of seriously wearing or breaking the spindle end on the rapidly turning rotor is avoided, because the maximum pressure that can be applied to the spindle is that which can be exerted by the spring.

To take a reading, back the index wheel off sufficiently to hold the spindle away from the turbine rotor. Then turn the spindle so that it can rest against the rotor. Then advance the index wheel slowly until the feeler plate is just free (part A of fig. 3-28). With the feeler plate just free, take and record the reading on the micrometer. Next, back the index wheel off, pull out the spindle, and turn it 180° so that it can rest against the casing. Again advance the index wheel until the feeler plate is just free and take another reading (part B of fig. 3-28). The difference between the two readings, taken with the rotor position micrometer, gives the relative position of the turbine rotor and casing. (The reading is taken on the casing as well as on the rotor because a single reading on the rotor would not take into account the wear in the end of the spindle.)

Readings are carefully taken and recorded just after the turbine is installed, and after each overhaul period. (At any future time, readings can be taken and compared with those on record.) Any difference between the readings taken at installation, or at overhauls, indicates thrust bearing wear, which should be checked as soon as possible. The normal oil clearance in the thrust bearing should be given consideration; it should not be mistaken for excessive wear.

Sometimes the rotor position indicator is installed so that readings can be taken from the dummy piston and cylinder; it may then be referred to as a dummy indicator.

Most modern turbine units are equipped with two different types of rotor position indicators. Both the HP and LP turbines have a rotor position indicator (thrust) mounted on the thrust bearing end of the turbine. The LP turbine in addition to the above indicator in some installations also has a rotor position indicator (relative) mounted on the end opposite the thrust bearing. Both indicators are used while the turbine is in operation.

The rotor position indicator's (thrust) primary purpose is to allow operating personnel to note a sudden movement of the rotor while underway in order to detect trouble such as a loose thrust collar, before damage to the turbine occurs.

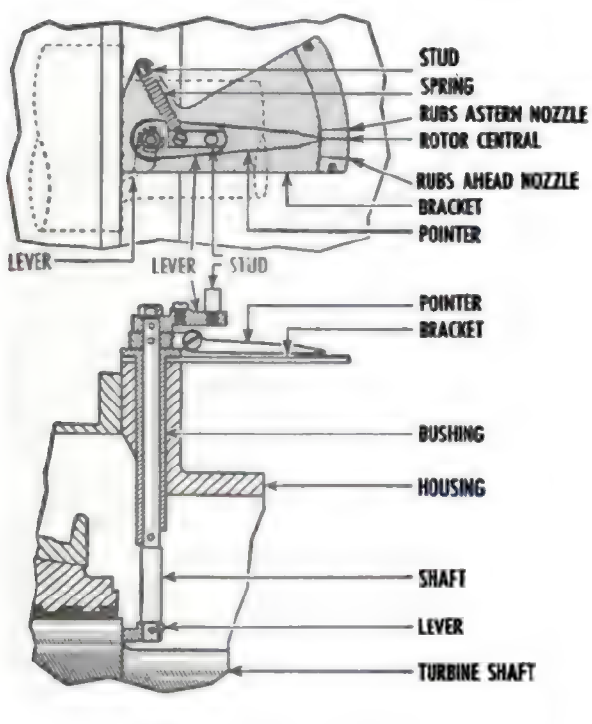
The rotor position indicator (relative) is used on the LP turbine to measure the differential expansion between the rotor and the casing caused by temperature changes. It indicates relative position of the rotor to the casing. The greatest variation in clearance occurs during maneuvering, when both the rotor and casing are subjected to large temperature changes. These changes cause expansions and contractions which differ in magnitude in both the rotor and casing because of unlike characteristics of both pieces.

The two types of indicators described below are used on most modern turbines to take the measurements discussed above. The indicator measures rotor position (thrust) if it is mounted on the thrust bearing end of the turbine and rotor

position (relative) if it is mounted on non-thrust bearing end.

Many turbines are equipped with an indicator which is mounted on the forward end of the turbine shaft, with its spindle in line with the centerline of the shaft. The linear speed of any point on the shaft approaches zero as the point nears the center of the shaft. Thus, when the indicator spindle touches the center of the shaft, it will suffer negligible wear. Therefore, in taking one reading, instead of two, and comparing that reading with the predetermined safe limits, the axial position of the shaft can be readily determined. This type of rotor position indicator has an additional advantage in that it does not pass through the casing of the turbine, and therefore does not require a stuffing box and packing gland.

Some modern main turbine installations are equipped with indicators similar to that shown in figure 3-29. The indicator is normally located at the end of the turbine opposite the thrust bearing. When not in use, the lever is held out of contact with the shoulder on the shaft by means of a spring. The indicator is used by moving the stud manually so as to bring the lever in contact with the shaft shoulder. The



47.24X
Figure 3-29.—Axial clearance indicator.

pointer, at its initial adjustment, indicates rotor center; and the indicator plate is marked to indicate the danger point of deviation (at which point adjustment must be made).

The most accurate means of determining whether the rotor is operating within safe limits is to check the total oil clearance of the thrust bearing. This clearance can be obtained by measuring the end play of the rotor. Methods of taking this measurement for various installations may differ but the basic principle is the same. With the thrust bearing completely assembled and the unit not in operation, the rotor is moved (jacked) as far as it will go, first in one direction and then in the opposite direction. The length of travel is measured with a precision instrument, such as a dial indicator.

One method of moving the rotor is as follows: Remove the upper half of the coupling guard and attach the dial indicator to the flanged surface of the bearing cap. To move the rotor forward, apply a bar between the after face of the coupling flange and the face of the adjacent cover. To move the rotor aft, the bar is applied between the forward face of the coupling flange and the face of the bearing cap. In each case a wooden block is used to prevent marring the metal surfaces. The end play (thrust bearing clearance) is obtained from the two readings of the dial indicator. If the end play is within designed limits, the rotor is operating within its allowable limits.

Additional information concerning journal and bearing clearances can be obtained from the manufacturer's technical manual for the specific installation

MAINTENANCE OF LABYRINTH AND CARBON PACKING RINGS

Worn labyrinth packing may be readily repaired by use of a chisel bar and a hand chisel. The chisel is struck with a hammer, and then advanced around the periphery of the packing a trifle less than the tool's width. Care must be taken that each new position of the chisel overlaps the preceding position. This procedure expands the LAND in height and draws it out to its original feather edge. The drawing out of the LANDS must be continued to give the packing clearance specified on manufacturer's drawings, instruction books, or Maintenance Requirement Cards. If the clearance is not available from plans, instruction books, or Maintenance Requirement Cards, the drawing of

LANDS should be continued until they come within 0.005 of an inch of touching the casing.

When overhauling carbon packing, it is recommended that the removed segments be immediately placed in a box in such a manner that adjacent segments of a ring will be next to each other, as shown by the marks on each end of each segment. Each segment is marked with the number of the ring of which it is a part:

1. Examine all sections of the carbon packing for scores, grooves, and wear in general. If necessary, renew or refit rings in accordance with manufacturer's plans, instruction books, or Maintenance Requirement Cards.
2. The springs must be carefully examined and tested. If they are found to be weak or corroded, they must be renewed.

PLANT MAINTENANCE

The maintenance of maximum operational reliability and efficiency of steam propulsion plants requires a carefully planned and executed program of inspections and preventive maintenance, in addition to strict adherence to prescribed operating instructions and safety precautions. If proper maintanance procedures are followed, abnormal conditions may be prevented.

Preventive inspection and maintenance are vital to successful casualty control, since these activities minimize the occurrence of casualties by material failures. Continuous and detailed inspection procedures are necessary not only to discover partly damaged parts which may fail at a critical time, but also to eliminate the underlying conditions which lead to early failure (maladjustment, improper lubrication, corrosion, erosion, and other enemies of machinery reliability). Particular and continuous attention must be paid to the following symptoms of malfunctioning:

1. Unusual noises.
2. Vibrations.
3. Abnormal temperatures.
4. Abnormal pressures.
5. Abnormal operating speeds.

Operating personnel should thoroughly familiarize themselves with the specific temperatures, pressures, and operating speeds of equipment required for normal operation, in order that departures from normal operation will be more readily apparent.

If a gage, or other instrument for recording operation conditions of machinery, gives an abnormal reading, the cause must be fully investigated. The installation of a spare instrument, or a calibration test, will quickly indicate whether the abnormal reading is due to instrument error. Any other cause must be traced to its source.

Because of the safety factor commonly incorporated in pumps and similar equipment, considerable loss of capacity can occur before any external evidence is readily apparent. Changes in the operating speeds from normal for the existing load in the case of pressure-governor-controlled equipment should be viewed with suspicion. Variations from normal pressures, lubricating oil temperatures, and system pressures are indicative of either inefficient operation or poor condition of machinery.

In cases where a material failure occurs in any unit, a prompt inspection should be made of all similar units to determine if there is any danger that a similar failure might occur. Prompt inspection may eliminate a wave of repeated casualties.

Abnormal wear, fatigue, erosion, or corrosion of a particular part may be indicative of a failure to operate the equipment within its designed limits or loading, velocity and lubrication, or it may indicate a design or material deficiency. Unless corrective action can be taken which will ensure that such failures will not occur, special inspections to detect damage should be undertaken as a routine matter.

Strict attention must be paid to the proper lubrication of all equipment, and this includes frequent inspection and sampling to determine that the correct quantity of the proper lubricant is in the unit. It is good practice to make a daily check of samples of lubricating oil in all auxiliaries. Such samples should be allowed to stand long enough for any water to settle. Where auxiliaries have been idle for several hours, particularly overnight, a sufficient sample to remove all settled water should be drained from the lowest part of the oil sump. Replenishment with fresh oil to the normal level should be included in this routine.

The presence of salt water in the oil can be detected by drawing off the settled water by means of a pipette and by running a standard

System, Subsystem, or Component	Reference Publications
High-Pressure, Low-Pressure and Cruising Turbines	

Bureau Card Control No.					Maintenance Requirement	M.R. No.	Rate Req'd.	Man Hours	Related Maintenance
MB	ZZZPTR6	B5	3037	D	1. Circulate oil through lube oil system. 2. Jack over idle turbines and reduction gears.	D-1	MM3	0.5	None
MB	ZZZFVAO	55	9752	M	1. Lubricate and operate all valve operating linkage.	M-1	MM3	0.5	None
MB	ZZZFTR6	A4	5409	Q	1. Take depth micrometer readings on the journal bearings of the main propulsion turbines.	Q-1	MM1	0.5	None
MB	ZZZFTR6	25	7724	Q	1. Lift the turbine sentinel relief valves by hand.	Q-2	MM3	0.2	None
MB	ZZZFTR6	65	A197	S	1. Measure thrust clearances of main propulsion turbines.	S-1	MM1 MM2 FN	8.0 8.0 8.0	None
MB	ZZZFTR5	94	5415	A	1. Inspect interior of turbine casings.	A-1	MMC MM2 FN	1.0 1.0 1.0	D-1
MB	ZZZFTR6	A4	5510	C	1. Clean, inspect, and preserve exterior of turbine casing.	C-1	MM2 FN	1.0 1.0	None
MB	ZZZFTR6	49	4052	C	1. Sound and tighten foundation bolts.	C-2	MM3	0.5	None
MB	ZXVFVA1	65	7727	C	1. Remove and test turbine sentinel relief valves.	C-3	MM3	2.5	None
MB	ZZZFTR6	65	A198	C	1. Inspect turbine thrust bearings.	C-4	MMC MM2 FN	4.0 8.0 8.0	S-1
MB	ZZZFTR6	65	A199	C	1. Inspect main propulsion bearings, journals, and oil deflectors. Measure clearances.	C-5	MMC MM2 FN	5.0 10.0 10.0	S-1 C-4
MB	ZZZFTR6	65	A500	C	1. Measure nozzle clearances of main propulsion turbines.	C-6	MMC MM2 FN	1.0 2.0 2.0	S-1 C-4
MB	ZZSFST5	74	4687	C	1. Clean and inspect main steam strainer.	C-7	MM1 FN	2.0 2.0 unit	None
MB	ZZZFTR6	65	A501	C	1. Inspect shaft packing and journals. Measure clearances.	C-8	MMC MM2 FN	3.0 5.0 5.0	C-5

MAINTENANCE INDEX PAGE
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Figure 3-30.—Maintenance Index Page.

chloride test. A sample of sufficient size for test purposes can be obtained by adding distilled water to the oil sample, shaking vigorously, and then allowing the water to settle before draining off the test sample. Because of its corrosive effects, salt water in the lubricating oil is far more dangerous to a unit than is an equal quantity of fresh water. Salt water is particularly harmful to units containing oil-lubricated ball bearings.

As an example, the maintenance requirements which shall be conducted in accordance with the 3-M System is shown in figure 3-30, (Maintenance Index Page).

CHAPTER 4

REDUCTION GEARS AND RELATED EQUIPMENT

This chapter deals primarily with reduction gears used in geared-turbine drive, ship's propulsion systems. It also includes information on related equipment such as bearings and shafting. The information which follows is supplementary to that given in Fireman, NAVPERS 10520-D.

The REDUCTION GEARS are the mechanisms to which the turbine rotor shafts are coupled, and which, through various arrangements of the gearing wheels, combine, convert, and reduce the high and different speeds of the high pressure and low pressure turbine rotor shafts to a single low speed for the main propulsion shaft and propeller.

A separate individual reduction gear, known as the CRUISING TURBINE REDUCTION GEAR, reduces the speed of the cruising turbine (where cruising turbines are used) to that of high pressure turbine shaft—the cruising turbine reduction gear output shaft being coupled to the shaft of the high pressure turbine.

High speed propellers are relatively inefficient, compared to the low speed propellers. They waste much of the horsepower churning up water, instead of using it to move the ship. The turbine speeds are, therefore, geared down to the appropriate speed for the size propeller the ship can carry—hence the term geared-turbine drive.

REDUCTION GEARS

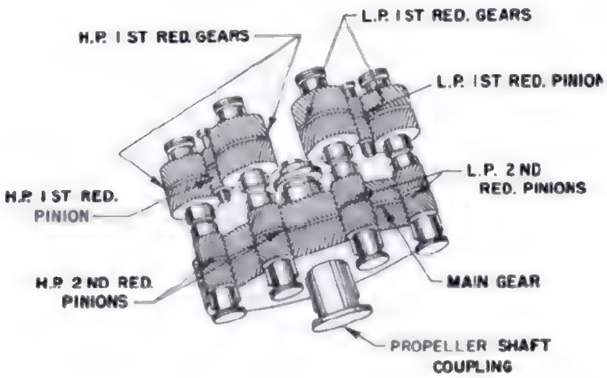
For turbine drives, double reduction gears are normally used. The locked train, or divided power path train gear (fig. 4-1) is used principally for combatant type ships. The articulated gear (fig. 4-2) or the nested gear (fig. 4-3) are commonly found on auxiliary and amphibious warfare ships. The single reduction type (fig. 4-4 and fig. 4-5) is installed on older ships where low turbine speeds permit the use of this gear arrangement on cruising turbine reduction and on many diesel propulsion units. Propulsion gears, driven by electric motors, are generally in accordance with figures 4-4 or 4-5. In such installations, either 1, 2, or 4 motors are used. For diesel engines, where the gear arrangements are also in accordance with figures 4-4 and 4-5, the diesels used (1, 2, 3, or 4) are generally connected to the propulsion gears by hydraulic clutches, electric clutches, or air actuated clutches. Engines which are unidirectional generally have either a reversing gear for astern operation or a controllable reversable pitch (CRP) propeller for astern operation. Gas turbines use gear arrangements similar to those for unidirectional diesels.

The construction, operation, and minor maintenance of main reduction gears (used with propulsion turbines) and reduction gears employed on auxiliary turbines, will be discussed in the following paragraphs.

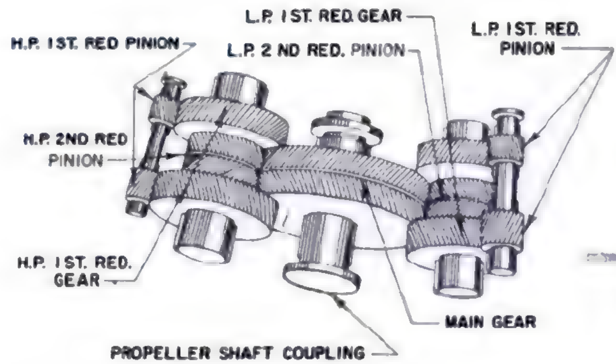
MAIN REDUCTION GEARS

Most reduction gearing in current combatant ships has double helical gears. The use of double helical gears produces a smoother action of the reduction gearing and avoids tooth shock. Since the double helical gear has two sets of teeth at complementary angles to each other, axial thrust, such as is developed in single helical gears, is eliminated. Each member of a double helical gear set should be capable of axial float in order to prevent excessive tooth loads due to mismatch of the two halves of the gear.

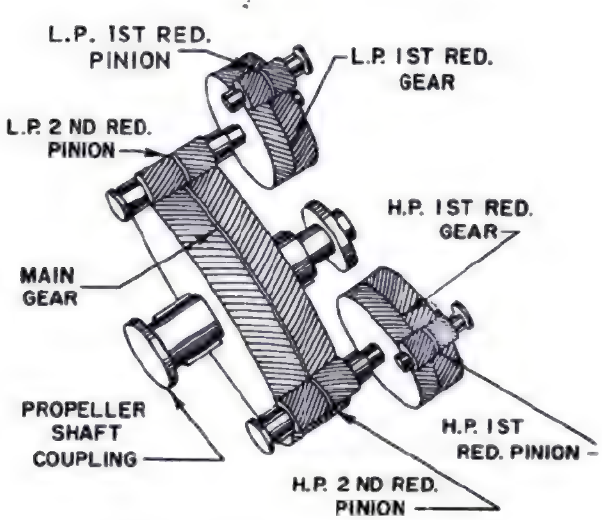
Reduction gears are classified by the number of steps used to bring about the speed reduction and the arrangement of the gearing. When two gears are run together and the driving gear is larger than the mating gear, the gear is referred to as a speed increaser. When the driving gear is smaller than the mating gear, it is referred to as a speed decreaser. The ratio of the speeds



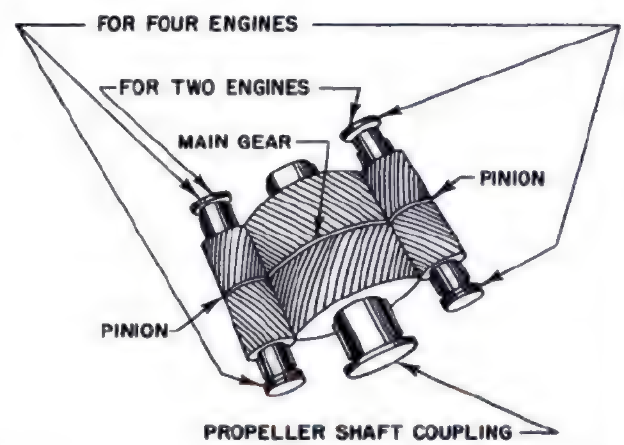
47.27
Figure 4-1. —Locked train, double reduction gear.



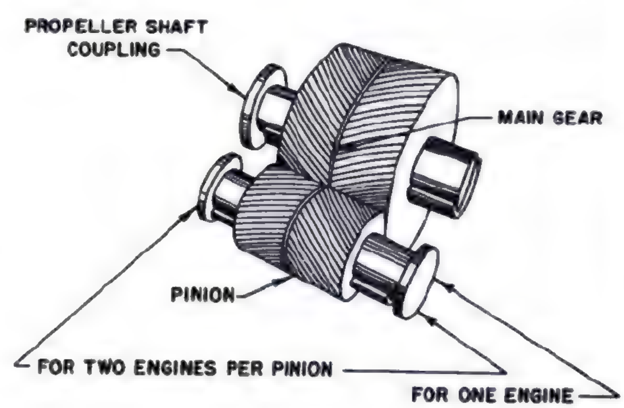
47.168
Figure 4-3.—Nested type, double reduction gear.



47.28
Figure 4-2.—Articulated, double reduction gear.



47.169
Figure 4-4. —Two pinion, single reduction gear.



47.170
Figure 4-5.—One pinion, single reduction gear.

is proportional to the diameters of the pinion and gear. When there are just two gears, the train is known as a single reduction gear (single speed increaser or decreaser). Double reduction gears are used to keep the size of the bull (large) gear, attached to the propeller shaft, from becoming too large.

Shipboard Applications

In a double reduction gear, a high speed pinion, connected to the turbine shaft by a flexible coupling, drives an intermediate first reduction

gear connected to a shaft having the second reduction pinion fastened to the other end.

When a single first reduction gear and the second reduction pinion each have two bearings and are connected by a quill shaft, the design is called ARTICULATED.

When a single high speed pinion is driving two intermediate first reduction gears connected by quill shafts to two separate second reduction pinions (each gear and pinion mounted in its own two bearings), this is known as an articulated LOCKED TRAIN GEAR. This type design is found aboard such ships as DLGs and DD692 destroyers.

In order to obtain an economical use of the fuel at low power, class destroyer and some others. This turbine, called the cruising turbine, is connected to the high pressure turbine through a single reduction gear. The cruising turbine and the pinion are bolted together and supported on three bearings. The direction of rotation of the cruising turbine is such as to cause the pinion bearing reaction to be in the upper half of the bearing. The HP and LP turbines are connected to the reduction gear by double ended "dental" tooth, or gear tooth, type flexible couplings.

The reduction gear shown in figure 4-2 is a parallel shaft, divided path, articulated reduction gear. The high speed high pressure pinion drives one first reduction gear. The second reduction pinions are coupled to these gears by dental tooth type flexible couplings and a quill shaft. Each gear and each pinion is supported in its own bearings.

In other ships, the economy of operation at low power is accomplished by using a combination HP-IP turbine or bypass arrangements. For low power, the high pressure, intermediate pressure (IP) and low pressure turbines operate in series. As speed and power are increased the high pressure and intermediate pressure turbines operate in parallel and in series with the low pressure turbine. Some classes of ships such as the DDG and DLG use this turbine arrangement. The reduction gear arrangement driven by the HP-IP turbine is similar to the DD692 reduction gear.

The nested type double reduction gear (fig. 4-3) employs no quill shafts and uses a minimum number of bearings and flexible couplings. This type gear, which is the simplest of all double reduction gears, is used on many older auxiliary ships.

Construction of Main Reduction Gears

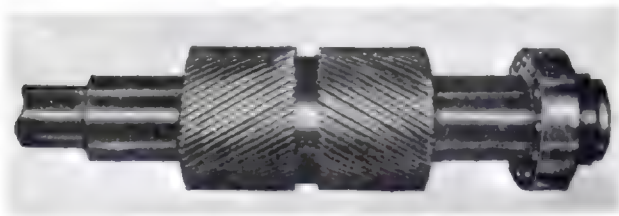
The main rotating elements in a main reduction gear unit (main gears and pinions) operate at high rotational speed and must be capable of transmitting tremendous power loads. Since even very slight unevenness of tooth contour and tooth spacing would cause the gears to operate noisily or even to fail, special precautions are taken to manufacture the gears to very close limits. The gears are cut in rooms in which the temperature and humidity are kept constant. Expansion and contraction of the gear-blank, during machining, are negligible; oxidizing, due to moisture in the air, is virtually eliminated. In addition, all gears are carefully checked for errors.

CASINGS.—Except for some small units, gear casings are of welded construction. Most gears have an upper and a lower casing and gear case covers. These casings are of box-girder construction with integral-bearing blocks. The low speed gear-bearing housing is an integral part of the lower casing. Gear case covers, bolted to the upper casing, are arranged so that their removal provides access to gearing and bearing caps. Inspection plates are provided in covers and gear cases so that the rotating parts may be sighted.

Casings are arranged for access to spray fittings so that fittings may be removed and cleaned. Turning gears, tachometer drives, sight flow and thermometer fittings, and thermocouples or resistance temperature-element (RTE) junction boxes are attached to gear casings.

GEARS.—In general, pinions are forged steel, one piece construction as shown in figure 4-6. For minesweeper applications, pinions are made of aluminum-bronze or other non-magnetic material.

The gear wheel construction and materials depend upon the size. For small gears, the entire gear wheel may be made from a single steel forging. Large gears are generally built up by welding. These sections usually are the shaft, the hub or center (which may be omitted when the webs are welded to the shaft), the webs and the rim in which teeth are cut. The shaft is always of forged steel. Where propeller-thrust bearings are located within the propulsion gear casing, a collar is located at the forward end of the low speed gear shaft, or an integral flange for attachment of thrust bearing facing collars is located on the after-end of



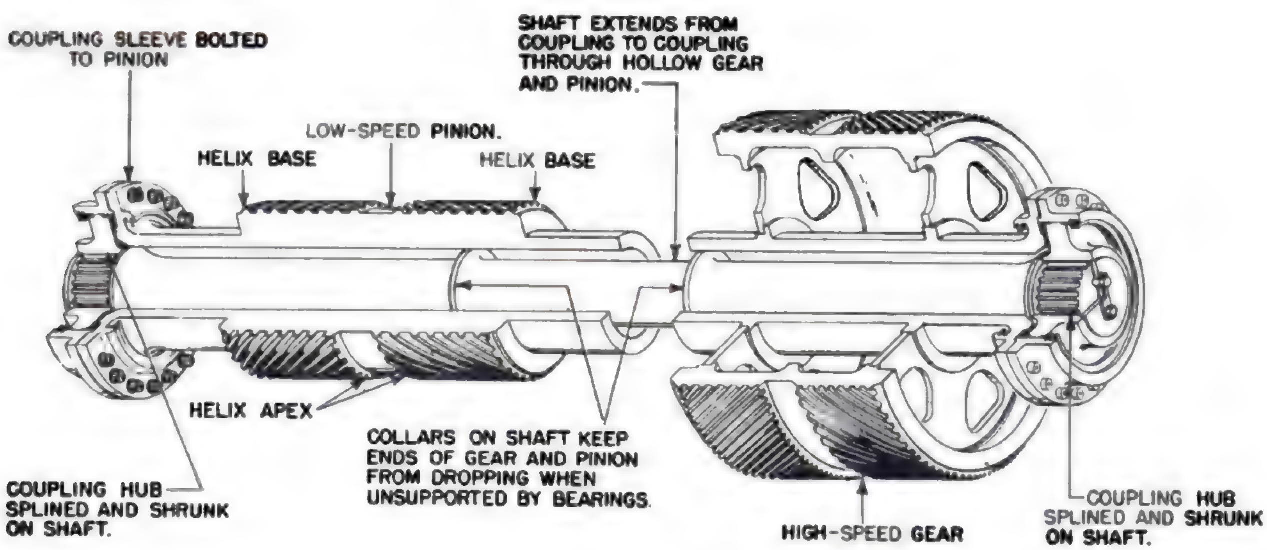
47.171
Figure 4-6. — Forged steel pinion.

the shaft, forward of the line shaft flange. Other types of construction used consist of a close-grained cast steel body welded to a shaft, with teeth cut directly in the casting or a cast-steel body pressed on a shaft and secured by fore and aft shrink rings and a locknut. Figure 4-7 illustrates a typical first reduction gear. Figure 4-8 shows a bull gear with flange for an after-thrust bearing. For minesweepers, gears are generally aluminum-bronze and discaloy; in some installations an aluminum-bronze rim with cast aluminum body is used.

In a double reduction articulated divided power path reduction gear, the high speed and second reduction pinion are usually machined from forgings. The first and second reduction gears are usually of a fabricated construction. The gear shaft and rim are made of good steel forgings. The rim and the shaft are assembled with steel webs, welded to the shaft and rim. In wide faced gears, the position of the steel webs, with respect to the gear teeth, is important in that it may affect gear tooth wear patterns. This assembly is stress relieved and heat treated for desired hardness.

Some gears are rough cut prior to heat treatment and the final finish operation will bring them to the proper size. The journals are then cut slightly oversize to permit a final finishing operation. The teeth are cut in a temperature controlled room. The cutting operation is a continuous operation; this avoids the heat generated in cutting from affecting the roundness of the finished gear. The air temperature control prevents changes in the ambient temperature from affecting the roundness of the gear. When the tooth cutting and the finishing operations are completed the journals are finished so that they are concentric with the axis. The assembly is then balanced. The bull gear is made in a similar fashion. Some first reduction gear and bull gears in naval use are keyed and locked to the shaft with a locking device. When the gears are all completed, the contact between pinion and gear is usually checked in a gear rolling machine before they are assembled in the gear case.

FLEXIBLE COUPLINGS.—Flexible couplings provide longitudinal flexibility between the turbine shaft and the pinion gear shaft. This perr



47.172
Figure 4-7. — Cutaway view of intermediate rotor assembly (first reduction gear).

47.173
Figure 4-8.—Bull gear with flange.

each shaft to be adjusted axially to its proper position.

In most installations the flexible couplings are of the gear tooth type. Power is transmitted through a floating intermediate member with external teeth that mesh with the internal teeth of the shaft rings (sleeve) mounted on the driving and driven shafts.

Figure 4-9 illustrates the design of the gear type flexible couplings that connect the main turbines to the high speed pinions of the main reduction gear. The couplings also allow for expansion of the turbine shafts, and take care of any slight misalignment between the main turbines and the reduction gears, such as thermal growth, and hull movements.

The design of the flexible couplings, which connect the first reduction gears and the second reduction pinions, is shown in figure 4-10. In this case, a quill shaft of high torsional flexibility is used, as the floating member, to obtain equal distribution of the load among the several elements of the gear train. The quill shaft runs inside the hollow bore of the intermediate speed gear and slow speed pinion. Figure 4-10 illustrates how flexibility is obtained between the first reduction gear and the second reduction pinion.

A flexible coupling is installed in the shaft between the cruising turbine reduction gear and the high pressure turbine. Figure 4-11 shows a flexible coupling such as is used on destroyers. In this coupling, the floating member is the two sleeves which are bolted together; the internal teeth of the sleeves mesh with the external teeth of the hubs mounted on the shaft.

Steady streams of oil from the supply passages of adjacent bearings are directed into coupling when the reduction gears operate. The oil is caught by projecting lips of the turbine and pinion flanges (fig. 4-9). Centrifugal action forces oil through the horizontal holes in the flanges to the coupling teeth. Oil is discharged from the teeth into coupling guards and then flows into the oil drain system.

TURNING GEARS.—All geared turbine installations are equipped with an electric motor-driven jacking or turning gear. A typical turning (jacking) mechanism is illustrated in figure 4-12. The unit is used for turning the main engine during warming-up and securing periods so that the turbine rotor may heat or cool evenly. (The rotor of a hot turbine or of one that is in the process of being warmed up, with gland sealing steam cut in, will become bowed or distorted if left stationary even for a few minutes.) The turning gear is used for other routine purposes such as for turning the reduction gear in order to bring the reduction gear teeth into view during routine inspection. In addition, the turning gear is used for the required daily jacking of the main engines.

The turning gear (fig. 4-12) is mounted on top and at the after end of the reduction gear casing. A shaft, extending from the end of the high pressure first reduction pinion over the bull gear to the after end of the reduction gear casing, connects to the turning gear by means of a manually operated jaw clutch. Engaging this clutch connects the pinion to an electric motor, through a train of gears, which usually consist of one or more sets of worm gears and one or more sets of spur or helical gears. Engaging the clutch and operating the motor will turn the high pressure first reduction pinion, causing the reduction gears, the main engines, and the main (propeller) shaft to turn. On some installations, the reduction ratio between the main shaft and the

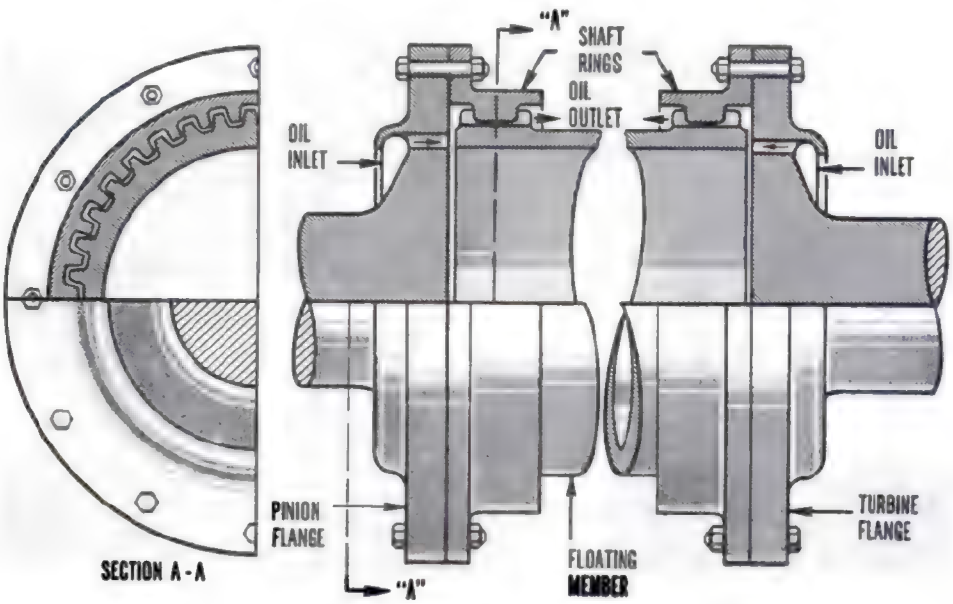


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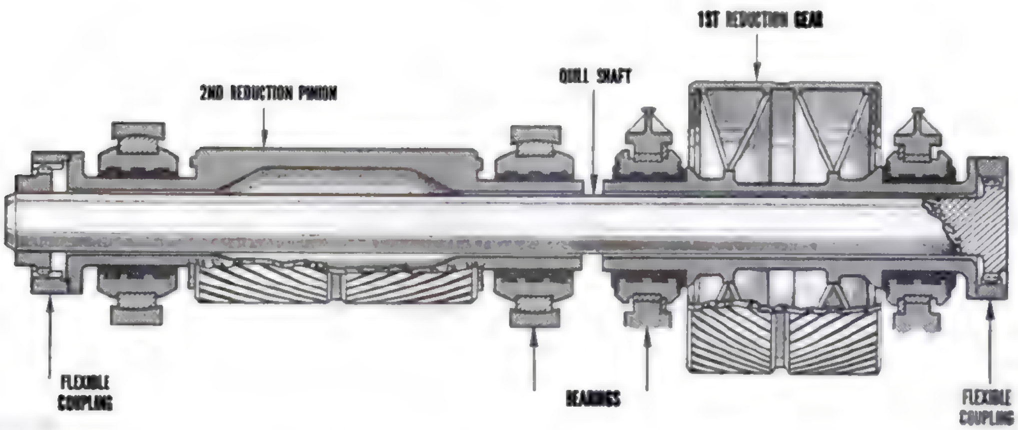
Figure 4-9. — Gear type flexible coupling.

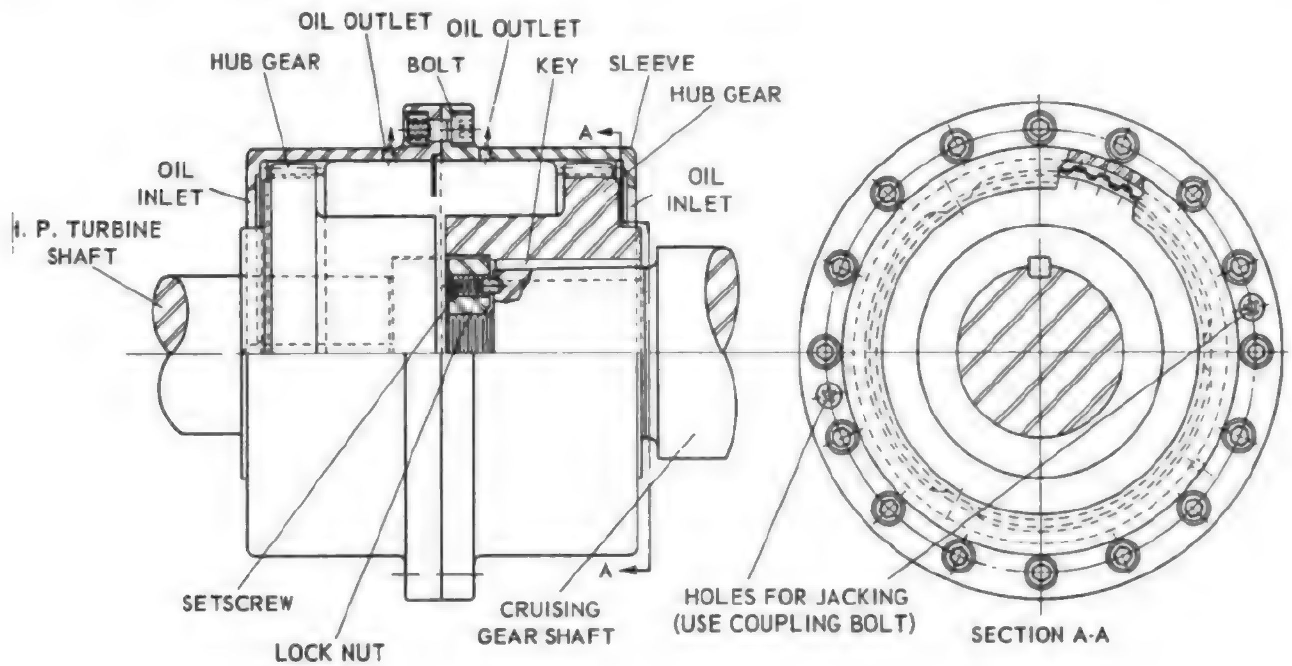


47.32X
Figure 4-10. — Quill shaft assembly.

electric motor may be as high as 17,000 to 1; with the motor turning and the turning gear engaged, the main shaft will make one and one quarter turns in approximately 15 minutes. Because of this high ratio, if the shaft was allowed to turn under steam at 1 rpm, the motor would overspeed and be seriously damaged.

The turning gear is equipped with a shaft locking device (fig. 4-13) which is used when it becomes necessary to lock a shaft against rotation while underway. A friction brake is installed on the first reduction worm shaft. Either a brake drum is mounted on the worm shaft or the shaft coupling serves as a drum.

With the jacking gear engaged and the brake set, a ship can go ahead on its other engines and the idle shaft will be held stationary. All geared turbine-drive ships have electric motor-driven turning gears similar to that shown in figure



47.33

Figure 4-11.—Flexible coupling between the cruising gear and the high pressure turbine.

4-14. This figure also illustrates a clamp-type brake used for locking the motor shaft. Some turning gears have positive locking devices which use internal and external gear teeth in engagement. Turning gear operated by air motors or by hand is generally used where continuous turning is not required.

In order to engage the jacking gear clutch it is necessary to first stop the shaft, either by stopping the ship or by using the astern turbine to stop and then hold the shaft stationary. Never, under any circumstances, attempt to engage the jacking gear with the shaft turning. Regardless of how slow the propeller shaft movement may be, damage to the motor or gears, or both, will occur.

REDUCTION GEARS FOR AUXILIARY MACHINERY

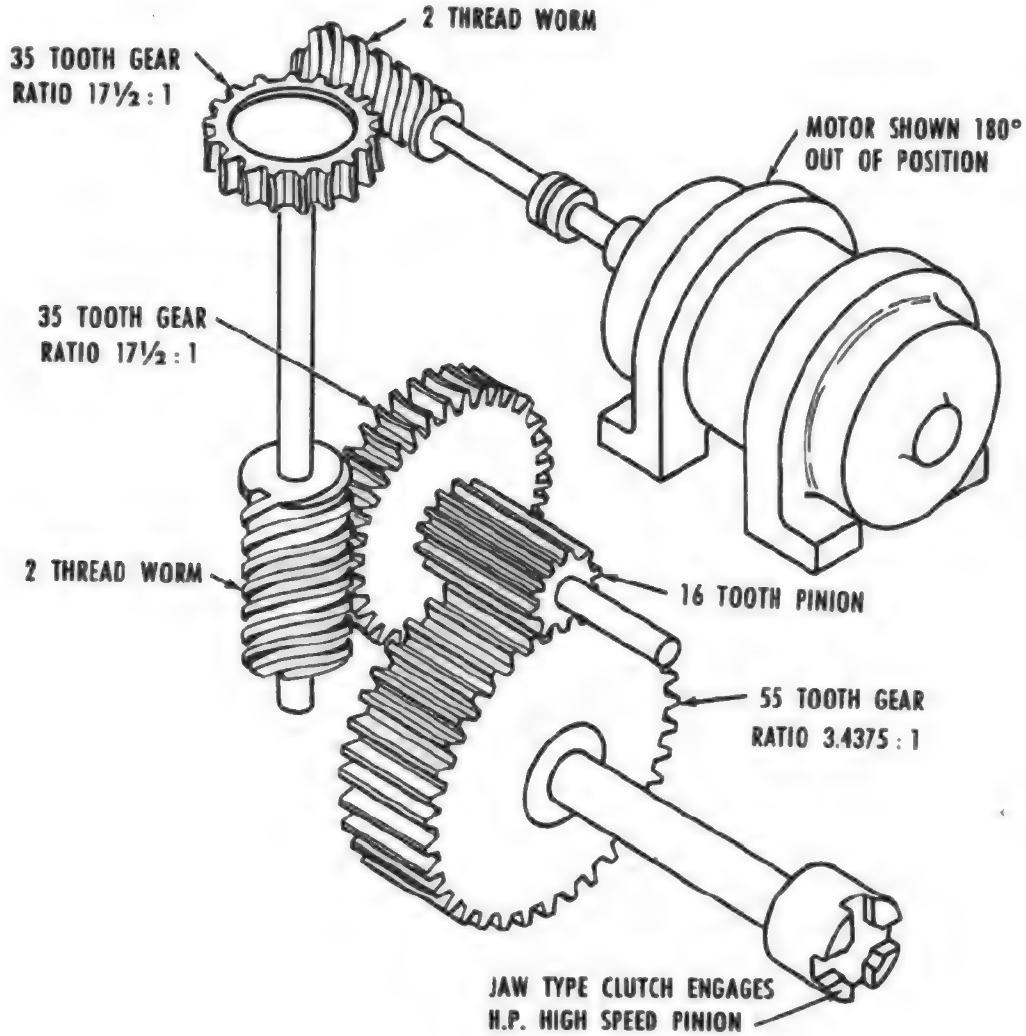
In the previous section of this chapter, main reduction gears of the double helix, double reduction type, were discussed. In smaller units of engineroom machinery, such as turbogenerators and turbine-driven pumps, there are different types of reduction gears.

Turbogenerators

On modern combatant ships, ship's service turbogenerators generally use a single reduction, single helix type of reduction gearing. An example of this type is found on the DD-692 class destroyers. A gear ratio of 8.3825 reduces the turbine speed of 10,059 rpm to the generator speed of 1200 rpm. The pinion is forged integral with the shaft. One end of the pinion shaft is flanged and bolted rigidly to the turbine shaft. On the other end, a high speed thrust bearing is mounted to maintain the axial position of the pinion and turbine rotor. The gear wheel is a steel forging, pressed and keyed on its shaft. One end of the shaft is coupled solidly to the generator shaft, the turbine end is extended to carry the gear that drives the oil pump and governor.

Main Circulating Pumps

Turbine-driven main circulating pumps employ single reduction, double helical gears with a ratio of about 8 to 1. These gears reduce the turbine speed of approximately 5000 rpm to the pump speed of 600 rpm. Lubrication of the reduction gear is provided by a gear type pump



47.34
Figure 4-12.— Jacking gear mechanism.

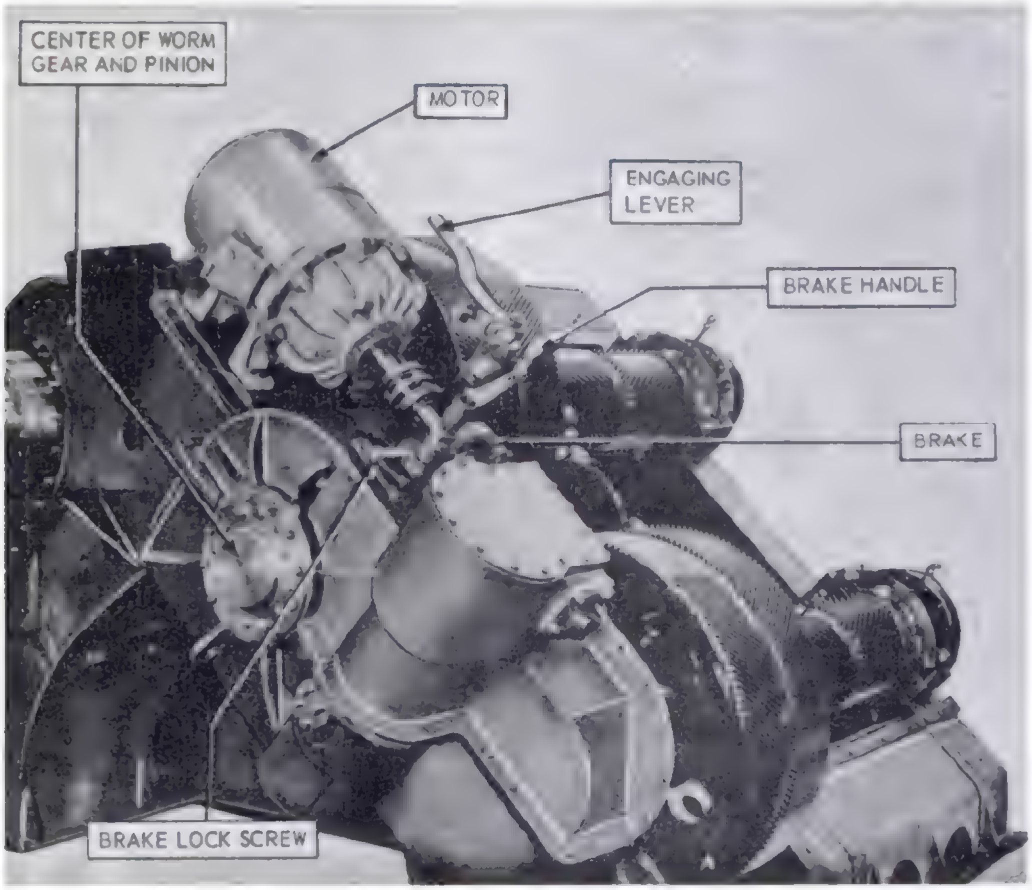
mounted on the lower end of the pinion shaft. Oil is sprayed through an orifice into the space between the gear teeth.

The weight of the combined rotating element of the pump and the driving unit is carried on a Kingsbury-type thrust bearing which supports a collar mounted at the upper end of the reduction gear shaft. The weight of the turbine rotor and pinion shaft is transmitted to the Kingsbury thrust bearing through the teeth of the double helical reduction gear.

The pinion is a solid forging, while the gear is constructed by welding a forged hub, forged rim, and plate sidewalls. The gear hub is bolted to a spider which is keyed to the gear shaft and held in place by the thrust collar which screws on to the shaft and locks with a setscrew.

Main Condensate Pumps

The condensate pump gear reduction frequently uses the worm type design to obtain good pump efficiencies at lower speed. The worm shaft and worm wheel reduce the turbine speed of 5534 rpm to the pump speed of 1145 rpm. The worm is cut in a solid, low carbon, nickel-steel forging. It is carried in two babbitt-lined split sleeve bearings and is located axially by a collar type thrust element. One end is tapered



47.35
Figure 4-13.—Main reduction gear after end, high pressure side, showing turning gear and propeller locking mechanism.

for mounting the turbine wheel while the other is squared for the application of a turning wrench.

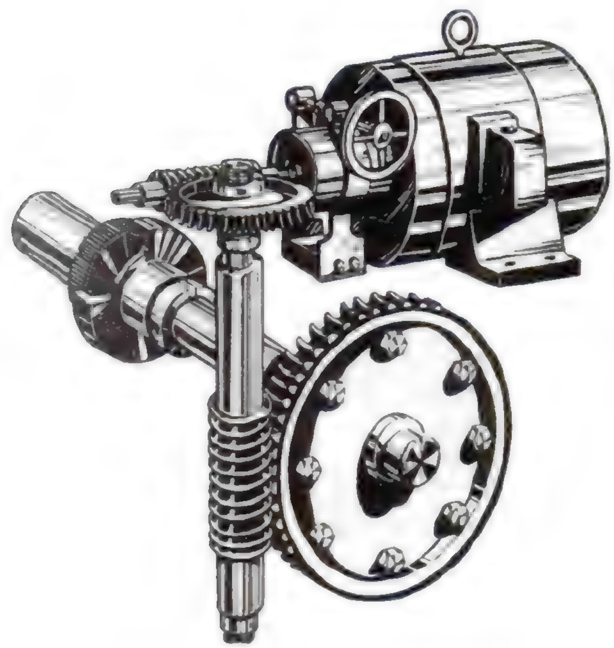
The worm wheel is a solid, nickel-bronze casting; it is pressed on a forged steel shaft which carries the drive pinion for the speed limiting governor and the driving half of the main pump coupling. The gear casing is cast steel specially designed to form a rigid support for the rotating elements. The gear case is of rugged construction to ensure proper alignment of the driving and driven elements, and is split horizontally to allow assembly and disassembly. The gear unit has a separate, closed pressure oil system; the bottom half of the gear casing serves as the oil sump.

REDUCTION GEAR CARE AND OPERATION

Compared with other units of engineroom machinery, reduction gears require very little care. With clean pure oil at the designed pressure and temperature, and with proper alignment, reduction gears will operate successfully for several years.

Lubrication

Efficient lubrication of reduction gears is of utmost importance. Oil at the designated working pressure and temperature must be supplied to the



47.174
Figure 4-14.—Rotating parts of electric motor-driven turning gear.

gears at all times while they are being turned over, either with or without load. Lubricating oil, Navy symbol 2190 TEP is used for the main reduction gears as well as for the turbines. Clean pure oil is essential for long life and successful operation of the gear.

Oil must be free from all impurities—especially such impurities as water, dirt, grit, and metallic particles. Care must be taken to remove metal flakes and fine chips as new gears are being worn into a working fit. Lint or dirt, if allowed to remain in the system, will clog the oil spray nozzles that lubricate the gears. Keep oil spray nozzles open at all times. Never alter the oil spray apparatus without proper authority.

Fine metallic particles which are not picked up by the magnets in the lube oil strainers, or dirt which may get through the strainers, may become embedded in the babbitted bearings and eventually score the journals. In addition, the mixture of dirt and metallic particles may erode metal from the gear teeth surfaces. The solution to this problem calls for clean, purified oil.

Effects of Acid and Water in Oil

Water in the oil is extremely dangerous. Even small amounts soon cause pitting and corrosion of the teeth. Acid is equally dangerous. The oil must be tested frequently for water as well as for acid content.

Corrective measures must be taken when salt water is found in the reduction gear lubricating oil system. Occasionally gross contamination of the oil by salt water occurs when a cooler leaks or when leaks develop in a sump which is integral with the skin of the ship.

Immediate location and sealing of the leak or removal of the source is not enough. Steps must also be taken to remove the contaminated oil from all steel parts and surfaces. Postponement of such treatment may cause badly corroded and pitted gears, journals, couplings, and bearings.

When the main engines are secured, the oil should be circulated until the temperature of the oil and of the reduction gear casing approximates the ultimate engineroom temperature. While the oil is circulated, the cooler should be operated and the engine should be jacked continuously. The purifier should also be operated while the oil is being circulated, and after circulation until water is no longer discharged from the purifier. This procedure will eliminate condensation from the interior of the main reduction gear casing.

Sump Oil Level

Since some reduction gears are located directly above the lubricating oil sump tank, positive means should be taken to ensure that the bull gear wheel will not dip into the oil. The proper oil level in the sump is indicated by a liquid level indicator. This oil level indicator registers two indications—normal level and low level. If the bull gear is permitted to rotate in the oil, the churning action will aerate the oil and cause the oil temperature to rise. Oil churning can also prevent full speed operation of the shaft. This condition can be noted by an overflow of foaming oil from the escape vent in the top of the gear casing. If this occurs, the engines must be slowed or stopped until the excess oil can be removed and normal conditions restored. Many bull gears have an oil exclusion pan fitted at time of manufacture to ensure against rotation of the gears in the oil.

Unusual Sounds

A properly operating reduction gear has a certain definite sound. Any unusual noises from the reduction gears should be investigated. The gears should be operated with caution until the cause is discovered and remedied.

BEARINGS

Although bearings in main propulsion units vary greatly in size, composition and lubrication requirements, their purposes are the same. Bearings are used to guide and support rotating or reciprocating elements and to prevent free axial or radial movement of these elements. Radial or journal bearings are designed to carry loads applied in a plane perpendicular to the axis of the shaft. Thrust bearings are designed to carry loads applied in the same direction as the axis of the shaft and are used to prevent free endwise movement.

Lubrication of bearings differs. For example, babbitt-lined bearings are lubricated by an approved lubricating oil while stern tube and strut bearings, which are lined with hardwood phenolic, or a rubber composition, are salt water lubricated. Bearings are designed to operate with a small oil clearance (the difference between the outside diameter of the journal and the inside diameter of the bearing is the oil clearance) which must always be maintained. With proper clearances and proper lubrication, bearings may operate successfully for many years. The information given in this training manual is of a general nature. Additional information may be obtained from chapter 9430 of Naval Ships Technical Manual. For details concerning a particular unit consult the manufacturer's technical manual.

MAIN REDUCTION GEAR AND PROPULSION TURBINE BEARINGS

Reduction gear bearings must not only support the weight of the gears and their shafts, but they must also hold the shafts in place against the tremendous forces exerted by the shafts and gears when they are transmitting power from the turbine shaft to the propeller shaft. Like other radial bearings in main engine installations, these bearings are of the babbitt-lined split type; however, instead of being spherically seated and self-aligning, the reduction gear bearings are rigidly mounted, and doweled into the bearing housings. The angular direction of the forces acting upon a main reduction gear bearing changes with the amount of propulsion power being transmitted by the gear. In order to obtain the best bearing performance when load is the greatest, reduction gear bearings must be positioned so that the heavy shaft load is not brought against the area where the bearing halves meet (the split). For this reason most of the bearings in a reduction gear are placed so that the split between the halves is at an angle to the horizontal plane.

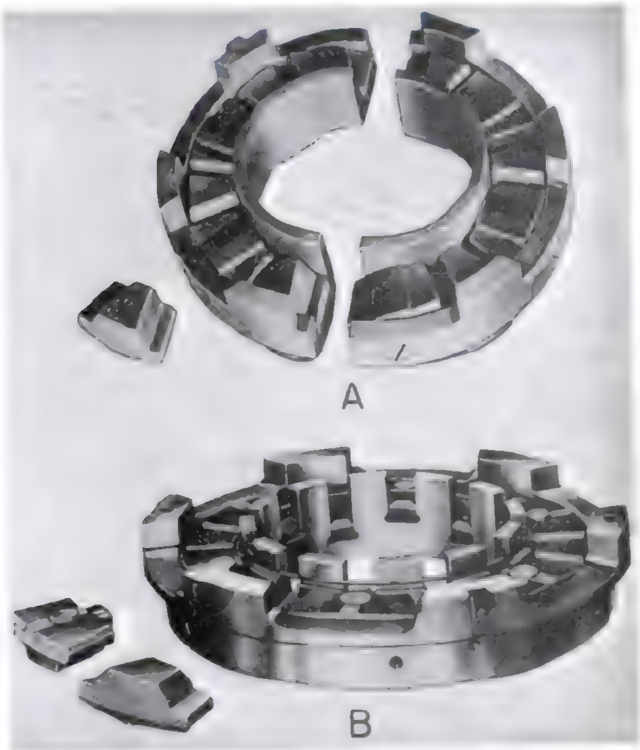
Turbine bearings, unlike reduction gear bearings, are self-aligning. This feature is obtained by providing a spherical seat for the bearing shells. Turbine bearings are pressure lubricated by means of the same forced-feed system that lubricates the reduction gear bearings.

MAIN THRUST BEARINGS

The main thrust bearing, which is usually located in the reduction gear casing, serves to absorb the axial thrust transmitted through the shaft from the propeller.

Kingsbury or pivoted segmental shoe thrust bearings of the type shown in figure 4-15 are commonly used for main thrust bearings. This type of bearing consists of pivoted segments or shoes (usually six) against which the thrust collar revolves. Ahead or astern axial motion of the shaft, to which the thrust collar is secured, is thereby restrained by the action of the thrust shoes against the thrust collar. These bearings operate on the principle that a wedge-shaped film of oil is more readily formed and maintained than a flat film and that it can therefore carry a heavier load for any given size.

In a segmental pivoted-shoe thrust bearing, upper leveling plates upon which the shoes rest and lower leveling plates equalize the thrust load among the shoes (fig. 4-16). The base ring, which supports the lower leveling plates, holds the plates in place and transmits the thrust on the plates to the ship's structure. Shoe supports (hardened steel buttons or pivots) located between the shoes and the upper leveling plates enable the shoe segments to assume the angle required to pivot the shoes against the upper leveling plates. Pins and dowels hold the upper and lower leveling plates in position, allowing ample play between the base ring and the plates to ensure freedom of movement (oscillation only) of the leveling plates. The base ring is kept from turning by its notched construction which secures the ring to its housing.



147.51X
Figure 4-15.—Kingsbury pivoted-shoe thrust bearing.

MAIN PROPULSION SHAFT BEARINGS

You will be required to watch and maintain the main propeller shaft bearings. The bearings which support and hold the propulsion shafting in alignment are divided into two general groups; the main line shaft bearings or spring bearings, and the stern tube bearings and the strut bearing.

Main Line Shaft Bearings or Spring Bearings

These bearings are of the ring or disk oiled babbitt-faced, spherical seat, shell type. This bearing (fig. 4-17) is designed primarily to align itself to support the weight of the shafting. In many of the older low powered ships, the bearing is not of the self-aligning type and consists only of a bottom half. The upper half of the assembly consists only of a cap or cover (not in contact with the shaft) to protect the shaft journal from dirt. The spring bearings of all modern naval ships, however, are provided with both upper and lower self-aligning bearing halves.

The brass oiler ring, shown in figure 4-17, is a loose fit; the inside diameter of the ring is greater than the outside diameter of the shaft plus sleeve. The rings are retained in an axial position by guides or grooves in the outer bearing shell. As the shaft rotates, the friction between the ring and the shaft is enough to cause the ring to rotate with the shaft. As the ring dips into the oil in the sump of the bearing, oil is retained on the inside diameter of the ring and is carried to the upper bearing by the ring. The action of the oil ring guides and contact of the ring on the upper shaft causes the oil to be removed from the ring and lubricate the bearing.

Spring bearing temperatures and oil levels should be checked hourly while underway. Inspection and maintenance will be done in accordance with the 3-M System.

Stern Tube and Stern Tube Bearings

The hole in the hull structure for accommodating the propeller shaft to the outside of the hull is called the stern tube. The propeller shaft is supported in the stern by two bearings—one at the inner end and one at the outer end of the stern tube—called stern tube bearings. At the inner end of the stern tube is a stuffing box packing gland (fig. 4-18) generally referred to as the stern tube gland. The stern tube gland seals the area between the shaft and stern tube and yet allows the shaft to rotate. Construction of the stern tube bearings is similar to that of the strut bearings. (See the next section of this chapter.)

The stuffing box is flanged and bolted to the stern tube. Its casting is divided into two annular compartments—the forward space being the stuffing box proper, the after space being provided with a flushing connection for providing a positive flow of water through the stern tube for lubricating, cooling, and flushing. This flushing connection is supplied by the firemain. A DRAIN CONNECTION is provided both for testing the presence of cooling water in the bearing, and for permitting sea water to flow through the stern tube and cool the bearing when underway, where natural sea water circulation is employed.

The gland for the stuffing box is divided longitudinally into two parts. The gland bolts are long enough to support the gland when it is withdrawn at least 1 inch clear of the stuffing box. This permits the addition of a ring of new

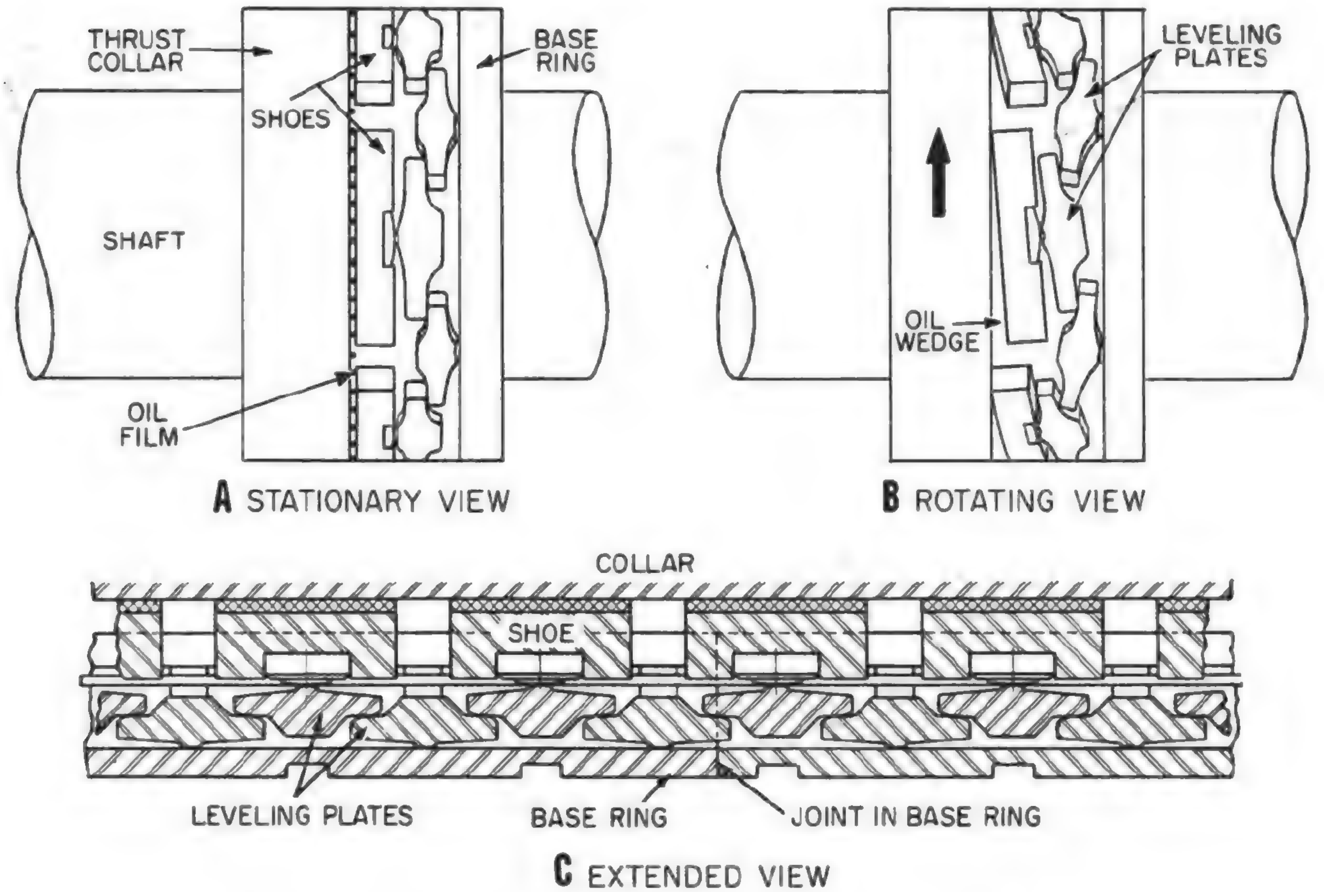


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Figure 4-16.—Diagrammatic arrangement of Kingsbury thrust bearing.

packing, when needed, while the ship is waterborne. Either braided flax packing or special semimetallic packing is used (ship's engineering drawings show the proper type of packing). This gland is usually tightened up, and flushing connection closed, to eliminate leakage when the ship is in port, and loosened just enough to permit a slight trickle of water for cooling purposes, when the ship is underway. Whenever packing is added to a stern tube, be sure that the gland is drawn up evenly by using a rule to measure the distance between the gland and stuffing box.

Shaft Seal And Inflatable Sealing Ring

The shaft seal and inflatable sealing ring (fig. 4-19) is widely used on modern Navy ships. The use of the shaft sealing assembly:

1. Eliminates the repairing or renewing of the shaft sleeve because it does not score or cut the sleeve.
2. Is fully automatic in operation, requiring no periodic adjusting.
3. Makes possible the removal and reinstallation of all parts without dismantling the shaft or shaft coupling.

In the tandem seal arrangement (fig. 4-19), the forward seal is the prime sealing unit and the aft seal is the spare unit. This arrangement provides for the immediate operation of the aft spare unit in the event of failure of the forward prime sealing unit.

The split inflatable rubber ring seal (fig. 4-19) installed aft of the prime seal assembly, is used

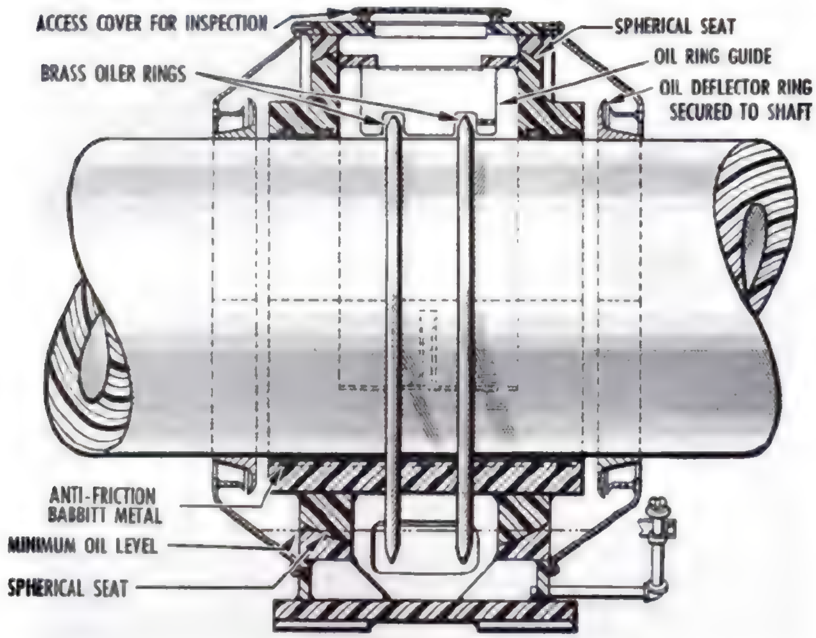

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Figure 4-17. — Main line shaft bearing.

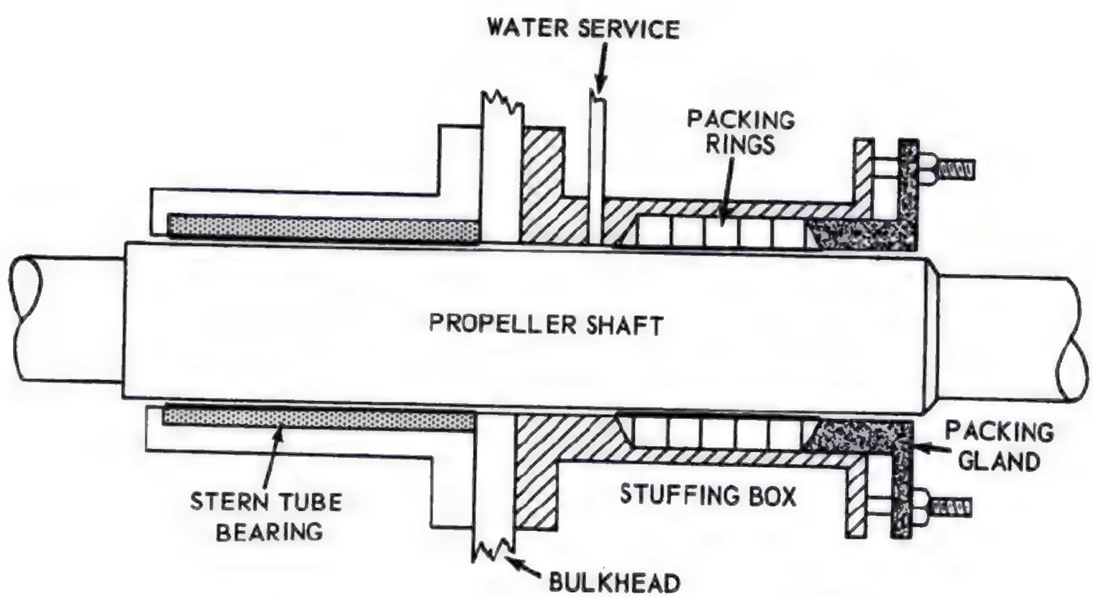

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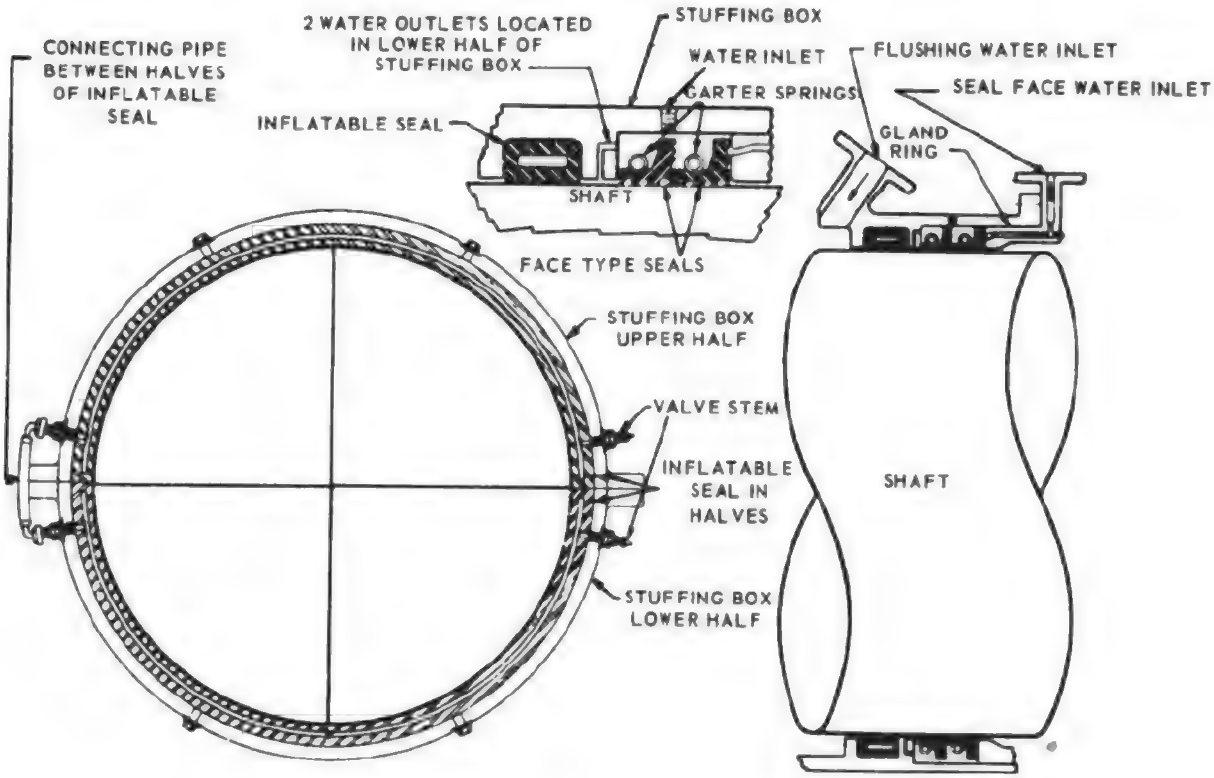
Figure 4-18. — Stern tube stuffing box and gland.



47.178
Figure 4-19.—Shaft seal and inflatable sealing ring.

when it is necessary to repair or replace the prime sealing elements with the ship waterborne. The following instructions are provided for guidance in operating and testing for split inflatable ring seal:

1. The split inflatable ring seal must not be pressurized except when ship is waterborne and shaft is at rest, NOT ROTATING.

2. The inflatable seal rings are tested in accordance with the 3-M planned Maintenance System or manufacturer's technical manual.

3. Pressure for inflating the split inflatable seal ring must not exceed 150 psi over sea pressure for surface conditions and must not exceed 150 psi over sea pressure for any submerged conditions up to a maximum pressure of 300 psi to avoid rupture of the inflatable seal. The charging air connection for pressurizing these seals should be provided with a needle valve, pressure gage and a relief valve. The pressure gage should have a range of zero to 300 psi and the relief valve should be set at 270 psi. Where it is demonstrated by actual sea tests at the 200-foot submergence level that satisfactory sealing can be obtained at a lower pressure for the type of inflatable seal installed, the relief valve setting may be lowered to accomodate the pressure as tested. As an alternate, a CO_2 cylinder of the Power-Pak 2 1/2-pound size inflator, or equal, can be used for pressurizing these seals. The CO_2 cylinders, if utilized, should also be equipped with fittings and a pressure gage for attaching to the inflatable ring valve stem, or housing connection, and should be stored in the vicinity of the seals for ready accessibility. The charging air connection, if utilized, should be equipped with a detachable connection for disconnecting from the inflatable ring valve stem. or housing connection, when not in use to avoid inadvertent pressurizing when the shaft is in operation. Attention is invited that hand or foot pumps are not to be

provided or used for pressurizing the inflatable seal rings since sufficient pressure cannot be obtained to effect adequate sealing.

4. Complete sealing is not to be expected under above test conditions or if inflatable seal ring is operated for repair at replacement of the prime sealing elements. The flow of water past the inflated seal ring should be restricted, however, and should not exceed one gallon per minute in order to permit repair or replacement of seals.

Strut Bearings

These bearings, as well as the stern tube bearings, are equipped with composition bushings which are split longitudinally into two halves. The outer surface of the bushing is machined with steps to bear on matching landings in the bore of the strut. One end is bolted to the strut.

Since it is usually impracticable to use oil or grease as a lubricant for underwater bearings, some other material must be employed for that purpose. There are certain materials that become slippery when wet, including synthetic rubber; lignum vitae, a hard tropical wood with excellent wearing qualities; or laminated phenolic material consisting of layers of cotton fabric impregnated and bonded with phenolic resin. Strips of this material, as shown in figure 4-20, are fitted inside the bearing.

A rubber composition is the type most used in modern installations. These bearings, of course, will never be seen by you while the ship is afloat, and chances are you will have little to do with them when your ship is in drydock, as then the navy yard men will be doing most of the work.

CARE OF BEARINGS AND JOURNALS

Properly operated bearings may give years of satisfactory service but like all units of engineroom machinery, they require periodic tests, inspections, and maintenance. When bearings are orginally installed, the manufacturer takes oil clearance readings which are recorded in accordance with the 3-M system. At regular intervals the ship's force must take these readings. Any difference between the old and the new readings will be the amount of bearing wear.

For main engine bearings the readings may be taken by depth gage or crown thickness as described in chapter 3 of this training manual. For bearings installed in auxiliary machinery or on the main line shafting, leads may be taken. Chapter 6 of this training manual gives information on the procedures for taking lead readings.

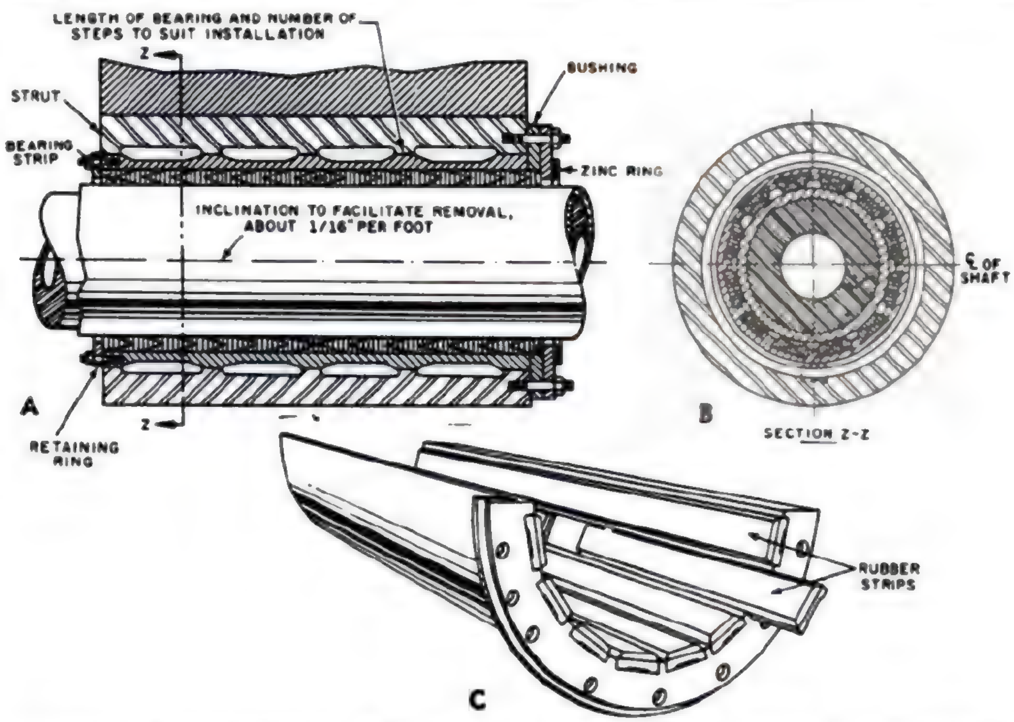


Figure 4-20. — Details of underwater strut bearing. (A) Longitudinal view, (B) Cross-sectional view, (C) Rubber stripping in the bearing. 47.41

For another example, a dial indicator may be used to take thrust bearing clearances as explained in chapter 3. In all cases, bearings should be inspected at regular intervals as prescribed in the appropriate chapters of the Naval Ships Technical Manual.

In most cases, the first indication of bearing trouble is a rise in temperature. Within limits, there is no objection to the rise in temperature of a running bearing; in fact it must take place. The rise in temperature is advantageous in that it is accompanied by a decrease in the viscosity of the lubricant. This decreases the internal friction of any given speed. There is no objection to running a bearing warm, provided the temperature reached is not sufficient to do harm, and provided there is no progressive increase in heat, indicating trouble. The thing to guard against is not necessarily a high running temperature of a bearing, but rather a rapid rise in temperature and an increase over the usual operating temperature of the bearing.

If the temperature of a bearing increases above its normal running temperature, the quality and quantity of the lubricant supplied to the bearing should be checked first. If possible increase the supply of lubricant to the bearing. In addition, increase the flow of circulating water to the coolers. If these measures do not reduce the bearing temperature, stop the unit and inspect the bearing. If the bearing has wiped, it should be replaced as soon as possible. However, if the wiping is slight, the bearing can probably be scraped to a good surface and restored to service, provided that readings are taken and the oil clearance is not excessive. For successful operation of bearings, the journal surfaces must be free from rust and be smooth and even at all times. To remove rust, ridges, and sharp edges, the journals should be honed with an oilstone or oilstone powder. Carborundum may be used but in this case great care must be taken to remove all particles. A dial indicator may be used to check the trueness of journal surfaces. First, clamp the indicator to the bearing base, or some other solid, stationary metal, so that the contact point of the spindle rests near the middle of the journal. Slowly rotate the shaft 360° and watch the needle on the dial. If the journal is out of round or has uneven spots, the needle will move. This motion is registered on the dial which is calibrated in one-thousandths of an inch. The total travel of the needle (plus and minus) will be the total runout of the journal.

SAFETY PRECAUTIONS FOR BEARINGS

Because of the similarities in operation of bearings in general, the safety precautions listed here apply to all main engine, main shaft, and auxiliary machinery bearings. If safety precautions are observed, many difficulties and breakdowns may be prevented.

1. Never use a piece of machinery if the bearings are known to be in poor condition.
2. Make certain that bearings have the proper quality and quantity of lube oil before starting the respective machinery.
3. Make certain the operating temperature of each bearing is not above the specified normal for particular load and speed conditions. Investigate and report abnormal temperature immediately.
4. Remember that rapid heating of the bearing is a danger sign. A bearing hot to the hand after an hour's operation may be all right, but the same heat reached in 10 or 15 minutes indicates trouble.
5. Newly installed bearings should, if possible, be given a run-in period with no load applied.
6. Use clean rags (lint free) in cleaning bearings shafting, and sumps.
7. In assembling and installing bearings with symmetrical halves, take care not to end-to-end one of the halves or to reverse the assembled bearing in its pedestal, as this may cover the lube oil inlet passage.
8. Clean out wells of self-lubricated sliding-surface bearings at frequent intervals, and see that the rings run freely and do not drag.
9. Refit or renew a wiped bearing.
10. When taking leads, make certain that the bearings halves are set up metal to metal.
11. Do not file or machine bearing joints.
12. After spotting-in a bearing, make certain that all shavings and dirt are cleaned from the parts.

PROPELLERS AND MAIN PROPULSION SHAFTING

The turbine and reduction gears convert the thermal energy of stem into usable mechanical energy. This mechanical energy is utilized through the propulsion shafting and the propeller.

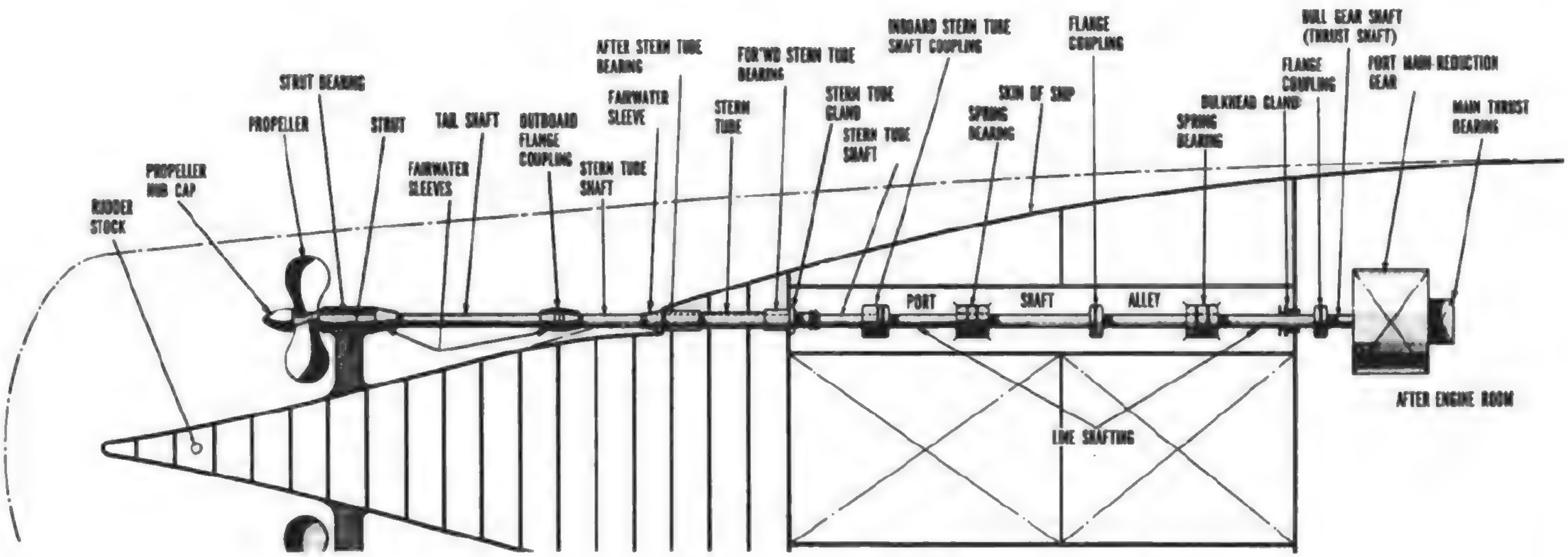


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Figure 4-21.—Diagrammatic arrangement of a main propulsion shafting.

MAIN PROPULSION SHAFTING

The MAIN PROPULSION SHAFTING, which may be up to 30 inches in diameter, is divided into two environmental sections—the inboard or line shafting and the outboard or waterborne shafting. (See fig. 4-21). The main propulsion shafting is made of forged steel (except in minesweepers where non-magnetic properties are required) and is usually hollow in sizes above 6 inches in diameter.

The line shafting consists of several sections of shaft, including the thrust shaft when the main thrust bearing is not located in the reduction gear casing. Those sections are usually joined together by bolts through FLANGE TYPE COUPLINGS which are forged integral with the shaft sections.

The outboard shafting consists of the propeller shaft or tailshaft upon which the propeller is mounted; the stern tube shaft which penetrates the hull of the ship and thus makes the transition between inboard and outboard shafting; and in some cases, an intermediate, or drop out shaft located between the propeller shaft and stern tube shaft. In some single shaft surface ships and submarines, the propeller shaft also functions as the stern tube shaft. The outboard shafting is protected from sea water corrosion by a covering of either plastic or rubber except that those areas which turn in bearings have shrunk on sleeves of bronze or copper nickel. Outboard shafting sections are usually joined to each other by integral flanges although some older ships may have a removable outboard shaft coupling known as a MUFF TYPE OUTBOARD COUPLING. The stern tube shaft is connected to the line shafting by a removable coupling known as the INBOARD STERN TUBE COUPLING.

Circular steel or composition shields known as fairwaters are secured to the stern tube after end and to the struts and are "faired in" to the shafting to reduce turbulence. This fairing is accomplished by a gradual reduction in diameter from that of the stern tube or strut to that of the shaft. In those cases where a flange is adjacent to a strut or the aft end of the stern tube, the fairwater may either extend beyond the flange (either forward or aft as applicable) and fair into the shaft or fair into a rotating coupling cover which is attached to the flange and shaft. The more recent ships have watertight rotating coupling cover filled with tallow which seals the flanged coupling from sea water.

PROPELLERS

The propellers, where the mechanical energy produced by the main engine is finally utilized are of various types of construction. They may be left-hand helices, turning counterclockwise in ahead direction when viewed from astern, or right-hand helices, turning clockwise. Normally, all starboard and centerline propellers turn clockwise and all port propellers turn counterclockwise. They may be of constant pitch, with pitch of blades identical at all points along the radius; variable pitch, with pitch of blades varying along the radius; or controllable pitch, with blades capable of being rotated within their sockets to change speed and direction of propeller thrust. They may be of solid construction, of single casting, or of built-up construction with individually cast blades bolted to the propeller hub. The number of blades may vary from three to seven.

CHAPTER 5

PUMPS

Pumps are vitally important to the functioning of your ship. If they fail, the power plants they serve fail. In an emergency, pump failures can prove disastrous. Maintaining the pumps in efficient working order is, therefore, a very important task of the Machinist's Mate.

The pumps with which you will be concerned are employed for such purposes as:

1. Feeding water to the boilers.
2. Drawing condensate out of the main and auxiliary condensers.
3. Supplying sea water to the firemain.
4. Circulating cooling water for coolers and condensers in the engineering spaces.
5. Pumping out the bilges or ballast water.
6. Circulating lube oil to bearings and gears of the main propulsion plant.
7. Transferring oil fore and aft, or to other ships.

It is not necessary to mention specifically all of the various spots in which pumps are located aboard your ship. You are probably acquainted with the location of most of them already, and in working as a Machinist's Mate you will soon learn the locations and purposes of many more. You should learn to operate, and to make minor adjustments and operational repairs to all the pumps found in the enginerooms and other spaces to which Machinist's Mates are assigned.

PRINCIPLES OF PUMP OPERATION

Pumps are used to move any substance which flows or which can be made to flow. Most commonly, pumps are used to move water, oil, and other liquids. However, air, steam, and other gases are also fluid and can be moved with pumps, as can such substances as molten metal, sludge, and mud.

A pump is essentially a device which utilizes an external source of power to apply a force to a fluid in order to move the fluid from one place to another. A pump develops no energy of its own; it merely transforms energy from the external source (steam turbine, electric motor, etc.) into mechanical kinetic energy, which is manifested by the motion of the fluid. This kinetic energy is then utilized to do work—for example, to raise a liquid from one level to another, as when water is raised from a well; to transport a liquid through a pipe, as when oil is carried through an oil pipeline; to move a liquid against some resistance, as when water is pumped to a boiler under pressure; or to force a liquid through a hydraulic system, against various resistances, for the purpose of doing work at some point. Every pump has a POWER END, whether it be a steam turbine, a reciprocating steam engine, a steam jet, or some kind of electric motor. Each pump also has a FLUID END, where the fluid enters (suction) and leaves (discharges) the pump.

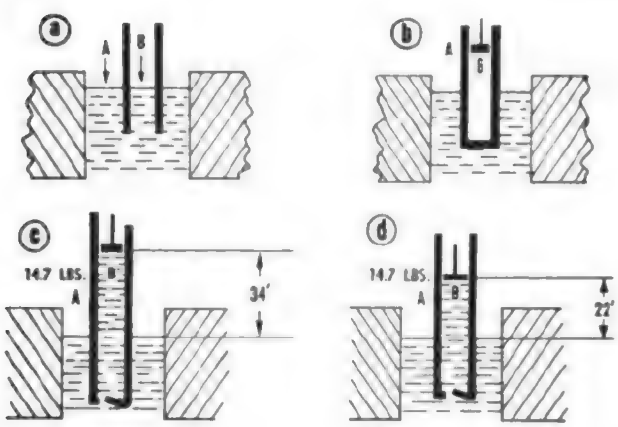
The addition of energy to a liquid by a pump usually results in an increase in pressure, which is generally referred to as HEAD. In connection with pump operation, you should know that there are four types of heads: (1) net positive suction head, (2) suction head, (3) discharge head, and (4) total head.

The NET POSITIVE SUCTION HEAD, or NPSH, is the suction pressure minus the vapor pressure expressed in feet of liquid at the pump suction. For example, in a feed booster pump with a deaerating feed tank operating at saturated conditions, the NPSH on the pump equals the pressure resulting from the height of the water above the booster pump suction.

THE SUCTION HEAD on a pump means the total pressure of the liquid entering the pump. In a deaerating feed tank operating under saturated conditions, the suction head of the feed

booster pump is equal to the NPSH plus the auxiliary exhaust pressure. The DISCHARGE HEAD means the pressure of the liquid leaving the pump, or the level of liquid with respect to the level of the pump on the discharge side. The TOTAL HEAD is the difference between the suction head and the discharge head. Suction head is usually expressed in feet of water if positive, and in inches of mercury if negative. When a pump operates below the level of a liquid, its suction end receives the liquid under a gravity flow. When it operates above the level of the liquid it must create a vacuum to which the liquid may be raised by atmospheric pressure or by another pump. ATMOSPHERIC PRESSURE has an important bearing on the suction of the pump.

The PRINCIPLE OF SUCTION FORCE, or suction lift, as applied to RECIPROCATING PUMPS is illustrated in figure 5-1. In diagram (a) the piston cylinder is open at both the top and bottom, so the liquid level at A and B is the same. In diagram (b) the cylinder is closed at the bottom. A piston has been inserted and partly withdrawn, thus creating a partial vacuum. When a valve at the foot of the cylinder opens, as in diagram (c), as a result of the lower pressure in the cylinder, the liquid at position (A) will lower in the well and rise through the cylinder to the new position (B) which is higher than the original position (B) shown in diagram (a). Assuming the vacuum is complete in diagram (c), and the liquid is water, the atmospheric pressure at point A has pushed the water up into the cylinder to a height of 34 feet at position B.



47.43
Figure 5-1.—Diagrams illustrating the principle of suction force.

You understand, of course, that the example is for a theoretical condition. Because of leaks, friction in the pipes, and gases in the liquid, a suction lift of about 22 feet is the maximum pull any shipboard pump can be designed to give; see diagram (d). When a pump is pumping certain liquids such as hot water, oil, or gasoline, some of the liquid will vaporize because of the vacuum on the suction side of the pump. This may cause the pump to become vapor bound; this will definitely reduce the possible suction lift.

The suction force principle applies to other types of pumps, as well as to the reciprocating type, though to a lesser degree and in a somewhat different manner. The CENTRIFUGAL, PROPELLER, and ROTARY pumps all may use suction force to a certain extent. Here a partial vacuum can be produced by the revolving mechanisms, instead of by the reciprocating plunger. An additional characteristic of centrifugal pumps is that they are not self priming because they will not pump air. Their casing must be flooded before they will function. In the JET PUMP, flow is maintained by the suction force created by a jet of water or steam passing through a nozzle at high velocity. These principles are explained in more detail later in the chapter.

TYPES OF PUMPS

Pumps constitute by far the most numerous units of auxiliary machinery aboard ship. Included among the types are centrifugal pumps, propeller pumps, reciprocating pumps, positive displacement rotary pumps, jet pumps such as eductors and air ejectors. The training manual Fireman, NAVPERS 10520-D, gives in clear, simple language and diagrams the basic principles of each of the many different types of pumps, and explains the characteristics of each type which make it adaptable to a particular service in the various engineering systems. Be sure to review that material carefully before studying this chapter.

Brief definitions for each of the general types of pumps and detailed descriptions of these pumps, and their several variations, are given in the following sections.

CENTRIFUGAL PUMPS

The basic principles of operation of the centrifugal pump are discussed in Fireman,

NAVPERS 10520-D. The centrifugal pump utilizes the throwing force of a rapidly revolving IMPELLER. The liquid is pulled in at the center or EYE of the impeller and is discharged at the outer rim of the impeller.

By the time the liquid reaches the outer rim of the impeller, it has acquired a considerable velocity. The liquid is then slowed down by being led through a volute or through a series of diffusing passages. As the velocity of the liquid decreases, its pressure increases; and thus its kinetic energy is transformed into potential energy.

There are many different types of centrifugal pumps, but the two which you are most likely to encounter on board ship are the volute pump and the volute turbine, or diffuser, pump.

In the VOLUTE PUMP shown in figure 5-2, the impeller discharges into a volute (a gradually widening channel in the pump casing). As the liquid passes through the volute and into the discharge nozzle, a great part of its kinetic energy is converted into potential energy.

In the DIFFUSER PUMP, shown in figure 5-3, the liquid leaving the impeller is first slowed down by the stationary diffuser vanes which surround the impeller. The liquid is forced through gradually widening passages in the diffuser ring (not shown) and into the volute. Since both the diffuser vanes and the volute reduce the velocity of the liquid, there is an almost complete conversion of kinetic energy to potential energy.

Centrifugal pumps may be classified in several ways. For example, they may be either SINGLE-STAGE or MULTISTAGE. A single-stage pump has only one impeller. A multistage pump has two or more impellers housed together in one casing; as a rule, each impeller acts separately,

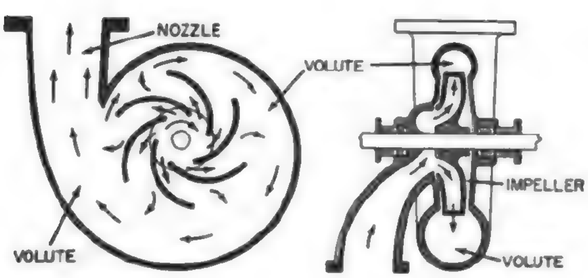


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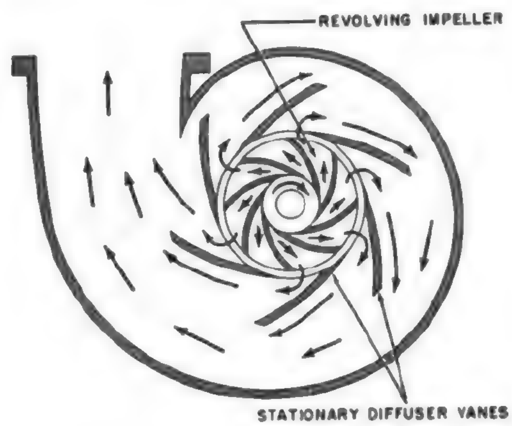
Figure 5-2.—Simple volute pump.



23.19
Figure 5-3.—Volute turbine pump.

discharging to the suction of the next stage impeller. Centrifugal pumps are also classified as HORIZONTAL or VERTICAL, depending upon the position of the pump shaft.

The impellers used on centrifugal pumps may be classified as SINGLE SUCTION or DOUBLE SUCTION. The single-suction impeller allows liquid to enter the "eye" from one direction only; the double-suction type allows liquid to enter the "eye" from two directions. Impellers are also classified as CLOSED or OPEN. Closed impellers have side walls which extend from the eye to the outer edge of the vane tips; open impellers do not have these side walls. Most centrifugal pumps used in the Navy have closed impellers.

Uses of Centrifugal Pumps

Centrifugal pumps are widely used on board ship for pumping nonviscous liquids. In the engineroom you will find several important centrifugal pumps: the feed booster pump, the fire and flushing pump, condensate pumps, auxiliary circulating pumps, and—in some ships—the main feed pump.

The FEED BOOSTER PUMP takes suction from the deaerating tank and discharges into the main feed pump suction. The booster pump provides a positive suction pressure for the main feed pump, and thus enables the main feed pump to handle feed water at high temperatures, without becoming vapor bound and losing suction. Feed booster pumps operate at or near constant

speed. In a turbine-driven feed booster pump, the speed is maintained approximately constant by the turbine speed limiting governor.

CONDENSATE PUMPS are vertical, one- or two-stage pumps which are used in closed and open feed systems. These pumps may be turbine driven or electric motor driven. The distinguishing features of condensate pumps are the large suction chambers and the large impeller "eye." The area above the impeller area is vented to the main condenser to prevent the pump from becoming vapor bound. The condensate pump is always located below the condenser, and consequently has a positive suction head into the impeller eye. In a turbine-driven condensate pump, the speed is maintained approximately constant by a speed limiting governor.

FIRE AND FLUSHING PUMPS are usually single-stage, double-suction, volute type centrifugal pumps, driven either by an electric motor or by a steam turbine. Turbine-driven units are fitted with a constant pressure governor and a speed limiting governor.

A typical MAIN FEED PUMP is shown in figure 5-4. Main feed pumps are of the high-speed, horizontal, turbine-driven type. Main feed pumps usually operate at a discharge pressure of 100 to 150 psig above the maximum operating steam drum pressure of the boiler, except on ships using 1,200 psig steam pressure. On such ships, the discharge pressure of the main feed pumps is approximately 200 to 300 psig above steam drum pressure. It is necessary for a main feed pump to operate at varying speeds to maintain a constant discharge pressure under all conditions of load. A constant pressure governor automatically regulates the admission of steam to the turbine so as to control the discharge pressure; in addition, a speed limiting governor is installed. However, on some newer ships, feed pumps are provided with a differential pressure governing system that maintains a constant differential pressure across the feed water regulating valve.

Construction of Centrifugal Pumps

As a rule, the casing for the liquid end of a pump with a single-suction impeller is made with an end plate which can be removed for inspection and repair of the pump. A pump with a double-suction impeller is generally made so that one half of the casing may be lifted without disturbing the pump.

Since the impellers rotate at very high speed, they must be carefully machined in order to minimize friction; and they must be balanced in order to avoid vibration. A close radial clearance must be maintained between the outer hub of the impeller and that part of the pump casing in which the hub rotates in order to minimize leakage from the discharge side of the pump casing to the suction side.

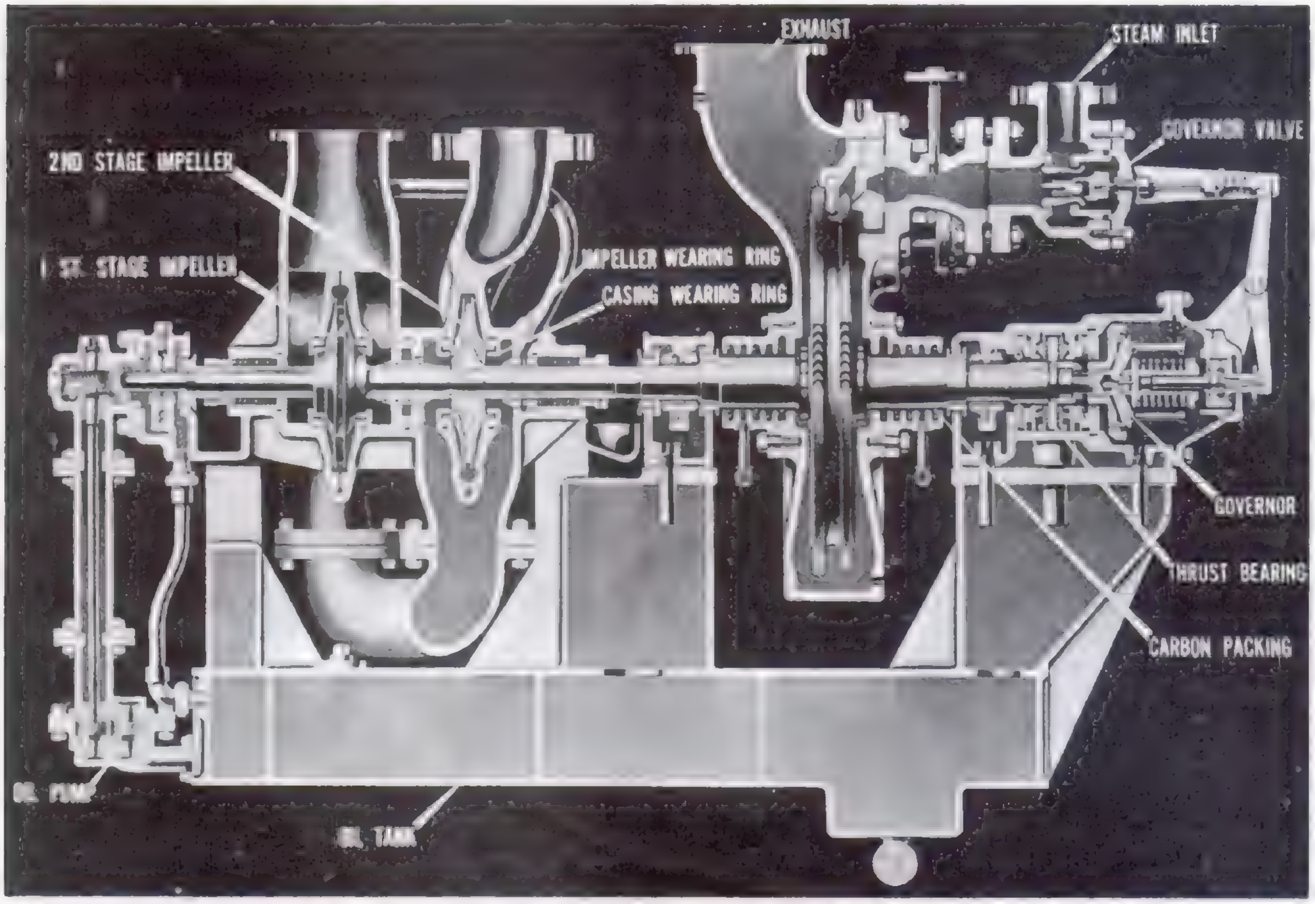
Because of the high rotational speed of the impeller and the necessarily close clearance, the running surfaces of both the impeller hub and the casing at that point are subject to relatively rapid wear. To eliminate the need for renewing an entire impeller and pump casing solely because of wear in this location, centrifugal pumps are designed with replaceable wearing rings. One ring is attached to the hub of the impeller, and rotates with the impeller; a matching ring is attached to the casing, and is therefore stationary. The replaceable ring on the hub of the impeller is called the IMPELLER WEARING RING, and the ring attached to the casing is called the CASING WEARING RING. (Wearing rings are shown on the main feed pump illustrated in fig. 5-4.)

It should be noted that some small pumps with single-suction impellers are made with a casing wearing ring only, and no impeller ring; in this type of pump, the casing wearing ring is fitted into the end plate.

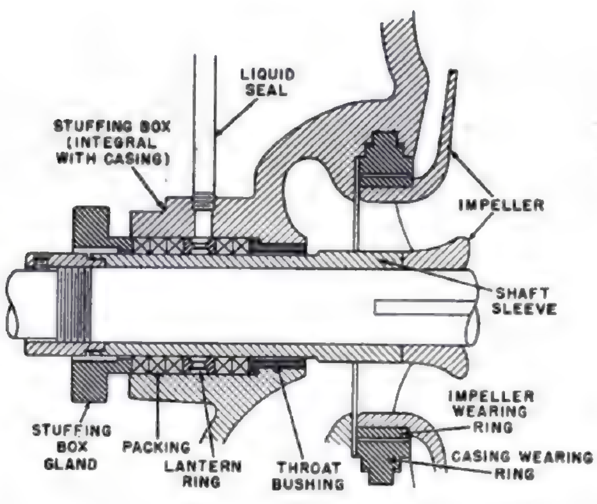
In many centrifugal pumps, the shaft is fitted with replaceable sleeves (fig. 5-5). The advantage of using sleeves is that they can be replaced more economically than the entire shaft.

Recirculating lines are installed on some centrifugal pumps to prevent the pumps from overheating and becoming vapor bound when the discharge is entirely shut off. Seal piping (liquid seal) is also installed to cool the shaft and the packing, to lubricate the packing, and to seal the joint between the shaft and the packing against air leakage. A lantern ring (spacer) is inserted between the rings of the packing in the stuffing box. Seal piping (fig. 5-5) leads liquid from the discharge side of the pump to the annular space within the lantern ring. The web of the ring is perforated so that water can flow in either direction along the shaft, between the shaft and the packing.

Bearings support the weight of the impeller and shaft, and maintain the position of the impeller, both radially and axially. Some centrifugal pumps have a built-in bearing



38.109
Figure 5-4.—Two-stage main feed pump.



28.35
Figure 5-5.—Stuffing box on centrifugal pump.

lubrication system, complete with lube oil pump, sump, cooler, strainer, and temperature and flow indicators. Other bearings are grease lubricated with grease cups and vent plugs constructed in the housing to allow for periodic relubrication.

The power end of a centrifugal pump may be either a steam turbine or an electric motor. For most constant-speed applications, the turbine drive has no particular advantage over the motor drive. On naval ships, however, where reliability and flexibility are essential considerations, most large centrifugal pumps are turbine driven. Smaller pumps, such as those used for in-port or cruising operation, are often motor driven.

The turbines used for centrifugal pumps are usually single-stage impulse turbines. As a rule, high-pressure centrifugal pumps are direct drive—that is, the impeller rotates at the same rpm as the turbine. However, some low pressure

centrifugal pumps have reduction gears installed between the turbine and the impeller; this allows the turbine to operate at a high speed and the impeller to operate at a lower speed, thus obtaining maximum efficiency from both turbine and pump.

PROPELLER PUMPS are used primarily where there is a large volume of liquid with a relatively low total head requirement. These pumps are usually limited to use where the total head does not exceed 40 to 60 feet.

The chief use of the propeller pump is for the main circulating pump (illustrated in Fireman, NAVPERS 10520-D). The main condenser circulating pump on most ships has an emergency suction for pumping out the engineroom.

The main condenser circulating pump is of the vertical propeller type. The pump unit consists of three major parts: the propeller, together with its bearings and shaft; the pump casing; and the driving unit.

The propeller of this pump is a multi-bladed screw propeller having a large pitch; the blades are thick at the roots and flare out toward the tips. The blades and hubs are cast or forged in one piece, and are then machined and balanced. The lower shaft bearing is a water-lubricated sleeve-type bearing; the shaft packing gland prevents excessive leakage of water between the casing and the shaft.

Because of the similarity of the centrifugal and propeller type pumps, the information given concerning care, maintenance, inspection, and precautions for centrifugal pumps is equally applicable for propeller pumps.

VARIABLE STROKE PUMPS

Variable stroke (also called variable displacement) pumps are most commonly used on naval ships as part of an electrohydraulic transmission for anchor windlasses, cranes, winches, steering gear, and other equipment. You will be responsible for maintaining and making minor repairs to hydraulic and related equipment outside your ship's engineering spaces. The information which follows is supplementary to that given in Fireman, NAVPERS 10520-D.

There are two general types of variable stroke pumps in common use: the axial-piston type and the radial-piston type. In the axial-piston type (fig. 5-6), the pistons are arranged parallel to each other and to the pump shaft; in the radial-piston type, the pistons are arranged radially from the shaft.

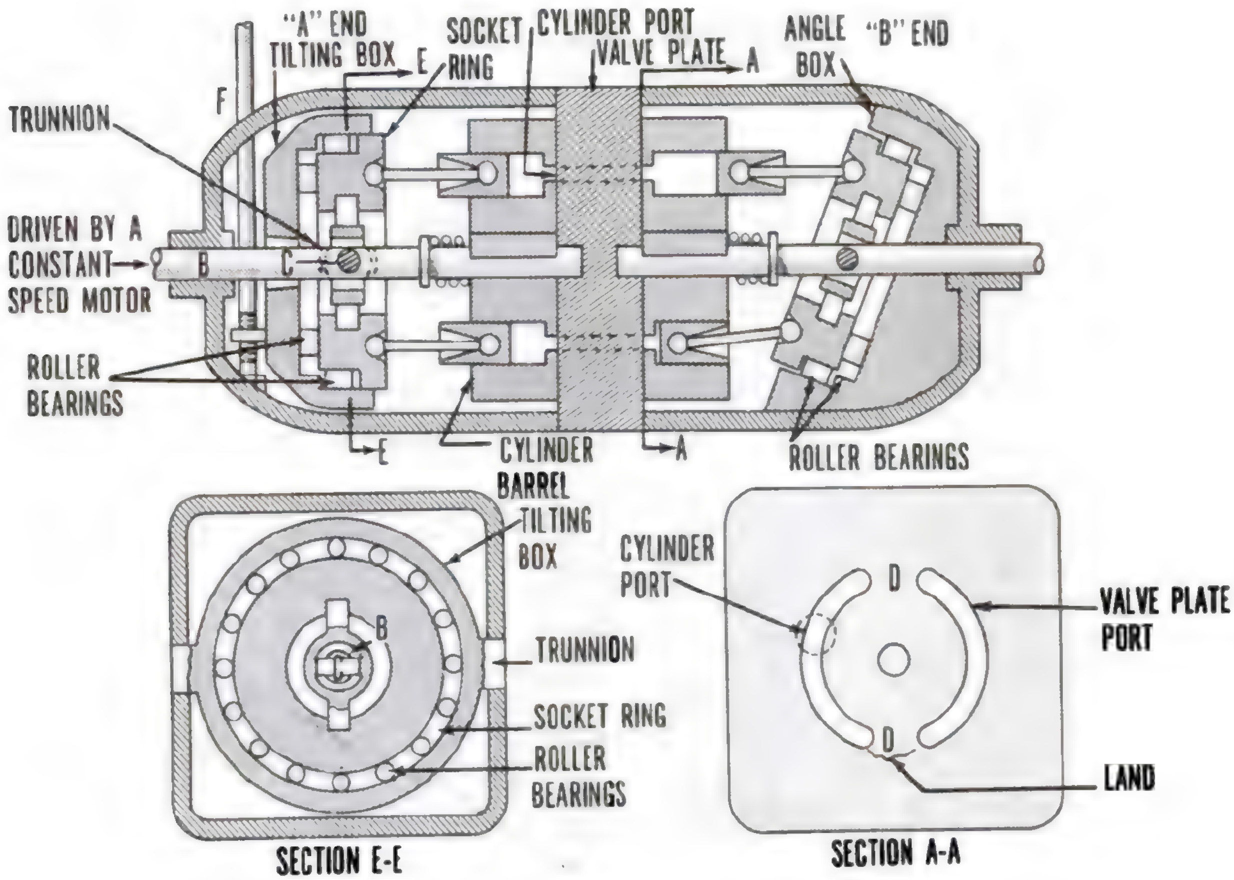
The VARIABLE STROKE AXIAL-PISTON PUMP usually has either seven or nine single-acting pistons which are evenly spaced around a cylinder barrel. An uneven number of pistons is always used in order to avoid pulsations in the discharge flow. (Note that the term CYLINDER BARREL, as used in this connection, actually refers to a cylinder BLOCK which holds all the cylinders.) The piston rods make a ball-and-socket connection with a socket ring. The socket ring rides on a thrust bearing carried by a casting called the TILTING BOX or TILTING BLOCK.

When the tilting box is at a right angle to the shaft, and the pump is rotating, the pistons do not reciprocate; therefore, no pumping takes place. When the box is tilted away from a right angle, however, the pistons reciprocate and the liquid is pumped.

When the variable stroke axial-piston pump is used as a part of a variable speed gear such as in electrohydraulic anchor windlasses, cranes, winches, and the power transmitting unit in electrohydraulic steering engines, the tilting box is so arranged that it may be tilted in either direction. Thus it may be used to transmit power hydraulically to pistons or rams, or it may be used to drive a hydraulic motor. In the latter use, the pump, which is driven by a constant speed electric motor, is called the A-end of the variable speed gear and the hydraulic motor is called the B-end.

The B-end unit of the hydraulic speed gear is exactly the same as the A-end of the variable stroke pump mentioned previously, except that it generally does not have a variable stroke feature. The tilting box is installed at a permanently fixed angle. Thus, the B-end becomes a fixed stroke axial-piston pump. Figure 5-6 illustrates an axial-piston type hydraulic gear with the A-end and B-end as a single unit; it is used in turrets for train and elevation driving units. For electrohydraulic winches and cranes, the A-end and B-end are in separate housings connected by hydraulic piping.

Hydraulic fluid introduced under pressure to a cylinder causes the piston to be pushed out. In being pushed out, the piston, through its connecting rod, will seek the point of greatest distance between the cylinder barrel and the socket ring. The resultant pressure of the piston against the socket ring will cause the cylinder barrel and the socket ring to rotate. This action occurs during the half revolution while the piston is passing the intake port of the motor, which is connected to the pressure port of the pump.



47.45X
Figure 5-6.—Axial-piston type hydraulic speed gear.

After the piston of the motor has taken all the hydraulic fluid it can from the pump, the piston passes the valve plate land and starts to discharge oil through the outlet ports of the motor to the suction inlet of the pump, and thence to suction pistons of the pump. The pump is constantly putting pressure on one side of the motor while it is constantly receiving hydraulic fluid from the other side. The fluid is merely circulated from pump to motor and back again.

The VARIABLE STROKE RADIAL-PISTON PUMP is similar in general principle to the axial-piston type just described, but the arrangement of component parts is different. In the radial-piston pump, the cylinders are arranged radially in a cylinder body which rotates around a nonrotating central cylindrical valve. Each cylinder communicates with horizontal ports in the central cylindrical valve. Plungers or pistons, which extend outward from each cylinder, are pinned at their outer ends to slippers which slide around the inside of a rotating floating ring or housing.

The floating ring is so constructed that it can be shifted off center from the pump shaft. When it is centered, or in the neutral position, the pistons do not reciprocate and the pump does not function, even though the electric motor is still causing the pump to rotate. If the floating ring is forced off center to one side, the pistons reciprocate and the pump operates. If the floating ring is forced off center to the other side of the pump shaft, the pump also operates but the direction of the flow is reversed. Thus it can be seen that the direction of flow and the amount of flow are both determined by the position of the cylinder body relative to the position of the floating ring.

The shipboard application of reversible type variable stroke pumps is in such hydraulic

transmission gear as steering mechanisms (discussed in chapter 16 of this training manual).

ROTARY PUMPS

Rotary pumps, like reciprocating pumps, operate on the positive displacement principle—that is, each rotation or each stroke delivers a definite quantity of liquid. Positive displacement rotary pumps have largely replaced reciprocating pumps for pumping viscous liquids in naval ships, as they have a greater capacity in relation to their weight and occupy less space.

Rotary pumps are most useful for pumping oil and other heavy, viscous liquids. In the engineroom this type of pump is used for lube oil service. In some ships a rotary fuel oil transfer pump is located in the engineroom. Rotary pumps are suitable for handling liquids over a wide range of viscosities. The power end of a rotary pump is usually an electric motor or an auxiliary steam turbine.

Rotary pumps are designed with very small clearances between rotating parts and stationary parts, in order to minimize slippage from the discharge side back to the suction side. Rotary pumps are designed to operate at relatively slow speeds in order to maintain these clearances; operation at higher speeds causes erosion and excessive wear, which result in increased clearances.

Classification of rotary pumps is generally based on the type of rotating element. In the following paragraphs, the main features of some common types of rotary pumps are discussed.

The SIMPLE GEAR PUMP has two spur gears which mesh together and revolve in opposite directions. One is the DRIVING GEAR, and the other is the DRIVEN GEAR. Clearances between the gear teeth (outside diameter of gear) and the casing and between the end face and the casing are only a few thousandths of an inch. As the gears turn, the gears unmesh and liquid flows into the pockets which are vacated by the meshing gear teeth. This creates the suction that draws the liquid into the pump. The liquid is then carried along in the pockets formed by the gear teeth and the casing. On the discharge side, the liquid is displaced by the meshing of the gears, and forced out through the discharge side of the pump.

In the herringbone gear, a modification of the simple gear pump, one discharge phase begins before the previous discharge phase is entirely complete; and this overlapping tends to give a steadier discharge pressure than is found in the simple gear pump. Power-driven pumps of this type are sometimes used for low pressure fuel oil service, lubricating oil service, and diesel oil service.

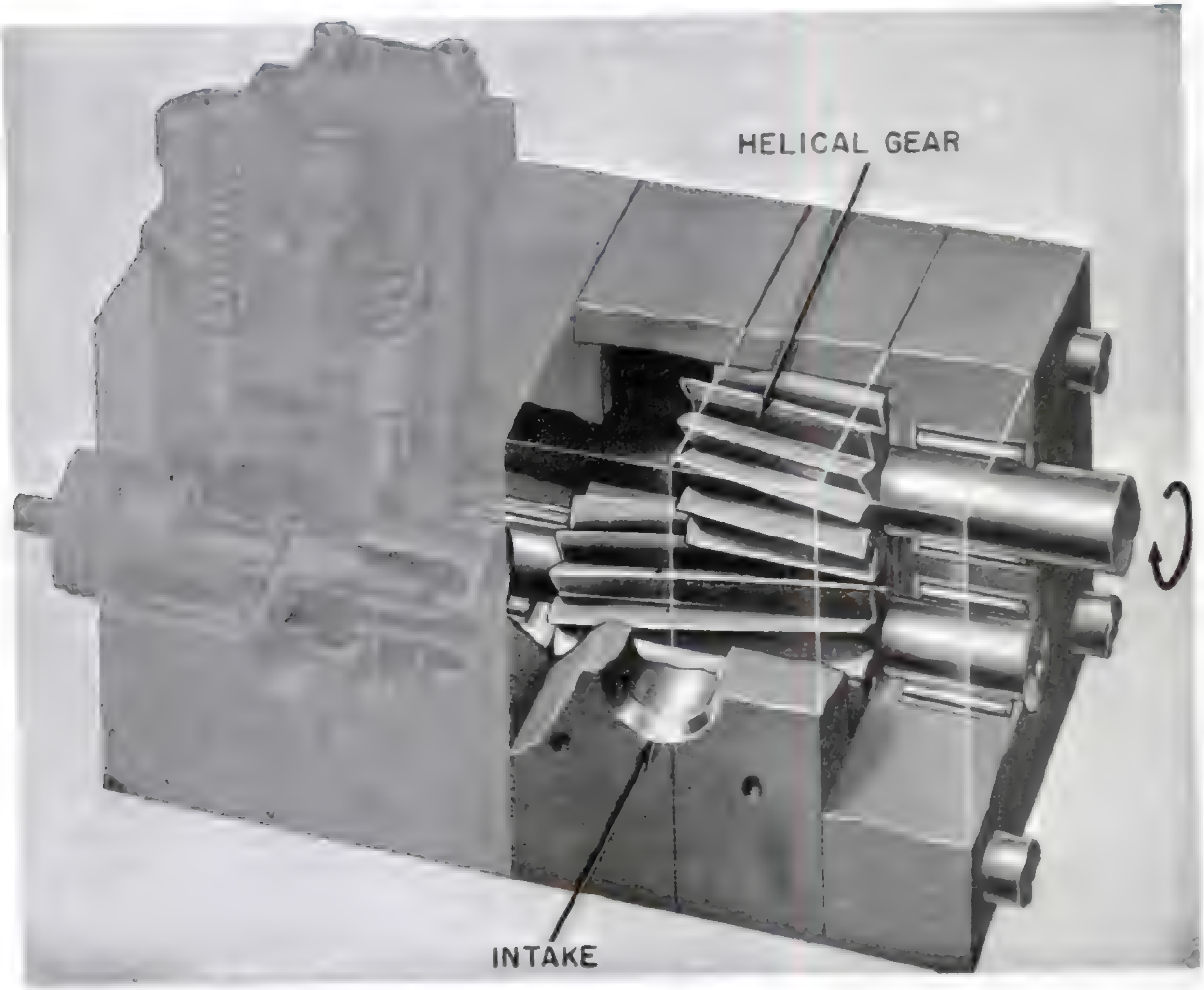
The HELICAL GEAR PUMP (fig. 5-7) is still another modification of the simple gear pump. Because of the helical gear design, the overlapping of successive discharges from spaces between the teeth is even greater than it is in the herringbone gear pump; and the discharge flow is, accordingly, even smoother. Since the discharge flow is smooth in the helical gear pump, the gears can be designed with a small number of large teeth—thus allowing increased capacity without sacrificing smoothness of flow.

The pumping gears in this type of pump are driven by a set of timing and driving gears, which also function to maintain the required close clearances while preventing actual metallic contact between the pumping gears. Metallic contact between the teeth of the pumping gears would provide a tighter seal against slippage; but it would cause rapid wear of the teeth because foreign matter in the pumped liquid would be present on the contact surfaces.

Roller bearings at both ends of the gear shafts maintain proper alignment, and so minimize the friction loss in the transmission of power. Stuffing boxes are used to prevent leakage at the shafts. The helical gear pump is used to pump nonviscous liquids and light oils at high speed. It can be used to pump heavy, viscous materials at lower speed.

The LOBE TYPE PUMP is still another variation of the simple gear pump. A lobe pump (heliquad type) is illustrated in figure 5-8. The lobes are considerably larger than gear teeth, but there are only two or three lobes on each rotor. The rotors are driven by external spur gears on the rotor shafts. Some lobe pumps are made with replaceable inserts (gibs) at the extremities of the lobes. These inserts take up the wear which would otherwise be sustained by the ends of the lobes; in addition, they maintain a tight seal between the lobe ends and the casing. The inserts are usually seated on a spring, and are thus able to automatically compensate for considerable wear of both the gibs and the casing. Replaceable cover plates (liner plates) are fitted at each end of the casing, where the lobe faces cause heavy wear.

There are several types of SCREW PUMPS. The main points of difference between the various types are the number of intermeshing screws and the pitch of the screws. Figure 5-9



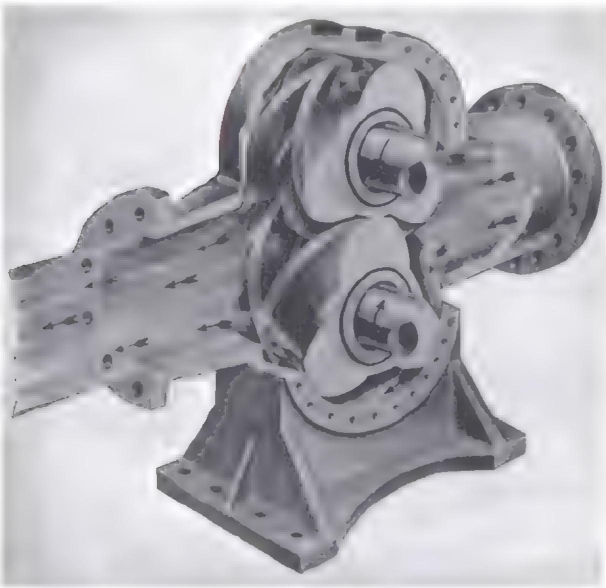
147.114
Figure 5-7. — Helical gear pump.

shows a positive displacement, double-screw, low-pitch pump. Screw pumps are primarily used for pumping all viscous fluids such as JP-5, diesel oil, and ND (Navy Distillate). The pump may be either motor or turbine driven.

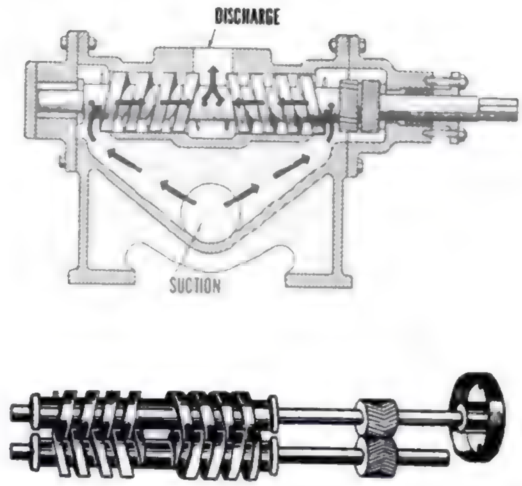
In the screw pump, liquid is trapped and forced through the pump by the action of rotating screws. As the rotor turns, the liquid flows in between the threads at the outer end of each pair of screws. The threads carry the liquid along within the housing to the center of the pump where it is discharged.

ROTATING PLUNGER PUMPS are used in the naval service for the following applications: fuel oil and diesel oil service, fuel oil booster and transfer service, fuel oil tank drains, and lubricating oil service.

Figure 5-10 illustrates the main operating parts of the rotating plunger pump (sometimes classified as a "cam-and-plunger" pump). The plunger is shown in three positions, illustrating the pumping process. The main body of the pump is a cylinder with the suction port entering through the side, as shown, in the upper left-hand corner. The drive shaft, concentric with the pump cylinder, carries an eccentric strap which has a slightly smaller diameter than the pump cylinder. The eccentric strap operates as a piston or "plunger." The eccentric arm plus the radius of the plunger is equivalent to the radius of the cylinder less the necessary operating



147.115
Figure 5-8. — Lobe pump (heliquad type).



38.105X
Figure 5-9.—Positive displacement double-screw low-pitch pump.

clearances. Therefore, with each revolution of the eccentric, the point of nearest contact of the plunger on the cylinder wall rotates completely around the cylinder. Motion of the plunger about its own center is constrained by a hollow arm, or slide, which extends from the plunger through a slot in the top of the cylinder, and above that point, through a slotted pin carried in a bearing which seals the cylinder space from the discharge space.

Referring to (1) in figure 5-10, it may be seen that liquid trapped in the right side of the cylinder will be forced through the hollow arm to the discharge line as the eccentric rotates counterclockwise. View (2) shows the next phase with the space on the left side opening, thereby creating a vacuum which causes liquid to flow in from the suction line. The next stage, shown at (3), illustrates the discharge port, at the bottom of the hollow arm, beginning to close. The discharge port is closed by the slide pin, during the suction portion of the stroke. When the eccentric turns slightly further, the point of contact of the plunger on the cylinder will pass over the suction port and trap the new charge on the discharge side, as shown in view (1).

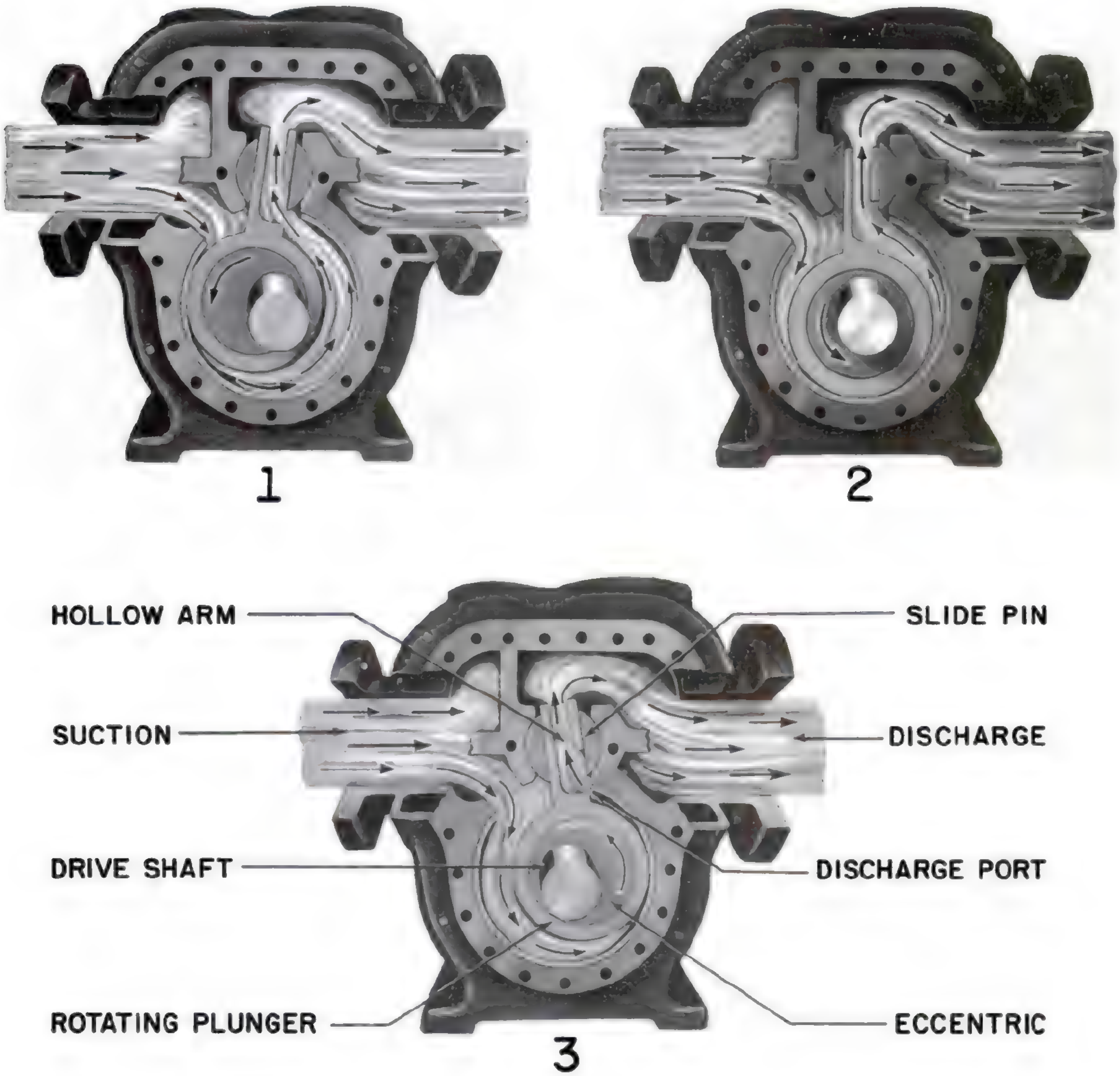
In order to reduce the tendency to pulsate, rotating plunger pumps usually employ two plungers whose driving eccentrics are 180° apart on the shaft. The plungers are separated by a diaphragm through which the shaft extends.

The MOVING-VANE TYPE PUMP, illustrated in figure 5-11, consists of a cylindrically bored housing with a suction inlet on one side, and a discharge outlet on the other side. A rotor (smaller in diameter than the cylinder) is driven about an axis so placed above the centerline of the cylinder as to provide minimum clearance between the rotor and cylinder at the top and maximum clearance at the bottom. (NOTE: Aboard some naval ships, the Blackmer vane pump has largely supplanted the pivoted vane, particularly for light hydrocarbon transfer such as JP-5. Additional information on such pumps can be obtained from the manufacturer's technical manual for the specific installation.)

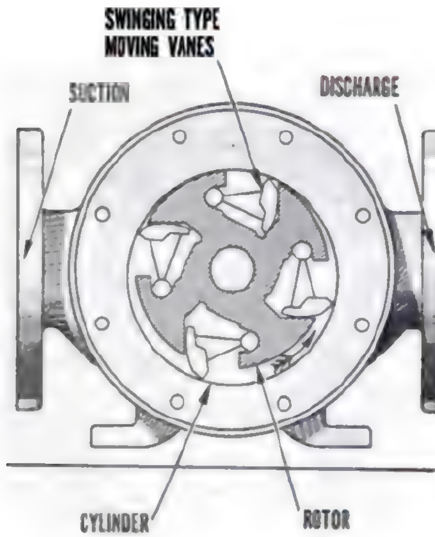
The rotor carries vanes which move in and out as it rotates to maintain sealed spaces between the rotor and the cylinder wall. The vanes trap liquid on the suction side and carry it to the discharge side where contraction of the space expels liquid through the discharge line. The vanes may swing on pivots, as shown in the illustration, or they may slide in slots in the rotor. Vane type pumps are used for lubricating oil service and transfer, and in general for handling lighter viscous liquids.

RECIPROCATING PUMPS

A reciprocating pump moves water or other liquid by means of a plunger or piston that



47.46
Figure 5-10.—Operating parts of the rotating plunger pump.



47.47
Figure 5-11.—Moving vane type pump.

reciprocates inside a cylinder. Reciprocating pumps are positive-displacement pumps; each stroke displaces a certain definite quantity of liquid, regardless of the resistance against which the pump is operating. Reciprocating pumps are usually classified as:

1. Direct acting or indirect acting.
2. Simplex (single) or duplex (double).
3. Single acting or double acting.
4. High pressure or low pressure.
5. Vertical or horizontal.

The reciprocating pump shown in figure 5-12 is a direct-acting simplex, double-acting, high pressure, vertical pump. Now let's see what all these terms mean, with reference to the pump shown in the illustration.

The pump is DIRECT ACTING because the pump rod is a DIRECT extension of the piston rod; and, therefore, the piston in the power end is DIRECTLY connected to the plunger in the liquid end. Most reciprocating pumps used in the Navy are direct acting.

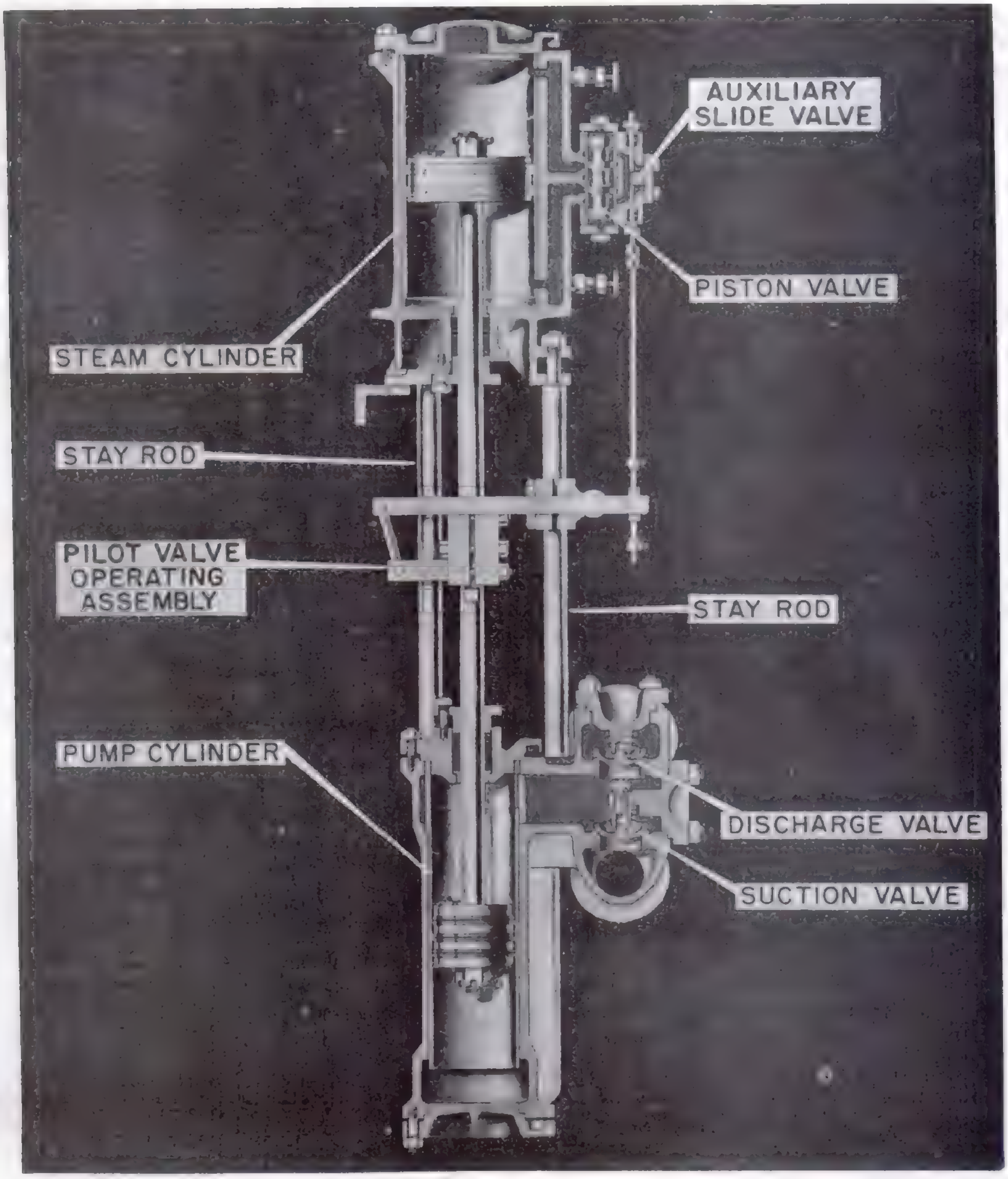
The pump shown in figure 5-12 is called a SINGLE or SIMPLEX pump because it has only one liquid cylinder. Simplex pumps may be either direct acting or indirect acting. A DOUBLE OR DUPLEX pump is an assembly or two single pumps, placed side by side on the same foundation; the two steam cylinders are cast in a single block, and the two liquid cylinders are cast in another block. Duplex reciprocating pumps are seldom found in modern combatant ships, but were commonly used in older ships.

In a SINGLE-ACTING pump, the liquid is drawn into the liquid cylinder on the first or SUCTION STROKE and is forced out of the cylinder on the return or DISCHARGE STROKE. In a DOUBLE-ACTING pump, each stroke serves both to draw in liquid and to discharge liquid. As one end of the cylinder is filled, the other end is emptied; on the return stroke, the end which was just emptied is filled and the end which was just filled is emptied.

The pump shown in figure 5-12 is double-acting, as are most of the reciprocating pumps used in the Navy. (NOTE: Only one of two sets of valves is shown in figure 5-12.) The pump illustrated is designed to operate with a discharge pressure which is higher than the pressure of the steam operating the piston in the steam cylinder. In other words, this is a HIGH PRESSURE pump. In a high pressure pump, the steam piston is larger in diameter than the plunger in the liquid cylinder. Since the area of the steam piston is greater than the area of the plunger in the liquid cylinder, the total force exerted by the steam against the steam piston is concentrated on the smaller working area of the plunger in the liquid cylinder; and, therefore, the pressure per square inch is greater in the liquid cylinder than in the steam cylinder. A high pressure pump discharges a comparatively small volume of liquid against a high pressure. A LOW PRESSURE pump, on the other hand, has a comparatively low discharge pressure but a larger volume of discharge. In a low pressure pump, the steam piston is smaller than the plunger in the liquid cylinder.

The standard way of designating the size of a reciprocating pump is by giving three dimensions, in the following order: (1) the diameter of the steam piston; (2) the diameter of the pump plunger; and (3) the length of the stroke. For example, a 12 x 11 x 18 inch reciprocating pump has a steam piston which is 12 inches in diameter, a pump plunger which is 11 inches in diameter, and a stroke of 18 inches. The designation enables you to tell immediately whether the pump is a high pressure or low pressure pump.

Finally, the pump shown in figure 5-12 is classified as VERTICAL because the steam piston and the pump plunger move up and down. Most reciprocating pumps in naval use are



38.98
Figure 5-12. — Reciprocating pump.

vertical; but you may occasionally encounter a HORIZONTAL pump, in which the piston moves back and forth rather than up and down.

The following discussion of reciprocating pumps is generally concerned with direct-acting, simplex, double-acting, vertical pumps, since most reciprocating pumps used in the Navy are of this type.

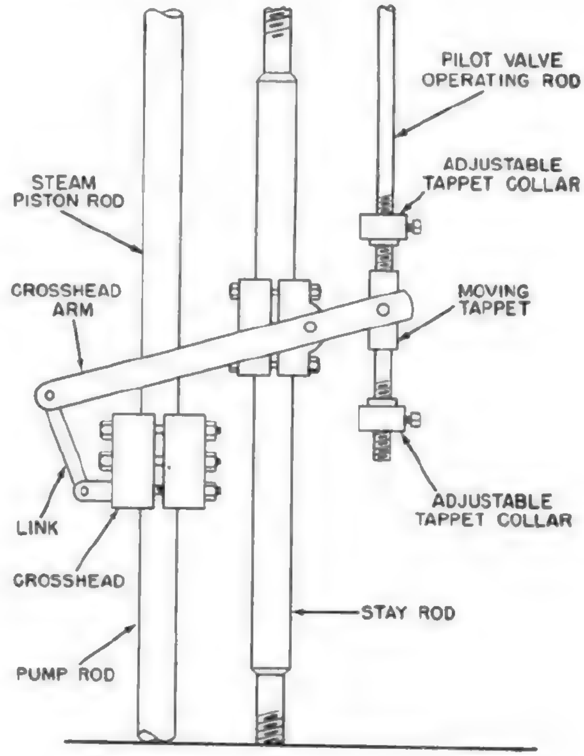
Construction of Reciprocating Pumps

The power end of a reciprocating pump consists of a bored cylinder in which the steam piston reciprocates. The steam cylinder is fitted with heads at each end; one head has an opening to accommodate the piston rod. Steam inlet and exhaust ports connect each end of the steam cylinder with the steam chest. Drain valves are installed in the steam cylinder, so that water resulting from condensation may be drained off.

Automatic timing of the admission and release of steam to and from each end of the steam cylinder is accomplished by a valve operating assembly which connects the pilot valve operating rod and the pump rod (shown in fig. 5-13). As the crosshead arm (sometimes called the rocker arm) is moved up and down by the movement of the pump rod, the moving tappet slides up and down on the pilot valve rod. The tappet collars are adjusted so that the pump will make the full designed stroke.

The piston type valve gear, commonly used for automatic timing, consists of a piston type slide valve and a pilot slide valve. The position of the pilot slide valve is controlled by the position of the main piston in the steam cylinder. At the completion of the down stroke of the pump, the crosshead arm moves the moving tappet against the upper adjustable tappet collar to actuate the pilot slide valve which admits steam to reposition the floating piston. The movement of the floating piston opens ports to admit steam to the underside of the piston in the steam cylinder and exhaust the steam above the piston; thus causing the piston to move upward. Once the pump has completed the upstroke, the cycle repeats itself in reverse.

The liquid end of a reciprocating pump has a piston and cylinder assembly similar to that of the power or steam end. The piston in the liquid end is often called a PLUNGER. A VALVE CHEST, sometimes called a WATER CHEST, is attached to the liquid cylinder; it contains two sets of suction and discharge valves, one



38.100
Figure 5-13.—Valve operating assembly.

set to serve the upper end of the liquid cylinder and one to serve the lower end. The valves are so arranged that the pump takes suction from the suction chamber and discharges through the discharge chamber on both the up and down strokes.

As in all Navy pumps, a relief valve is installed in the discharge piping between the pump and the discharge valve. The relief valve is to protect the pump and the piping against excessive pressure.

Uses of Reciprocating Pumps

Reciprocating pumps are used for two purposes in the main machinery spaces; as fire and bilge pumps and as emergency or auxiliary feed pumps. Reciprocating pumps are very good for emergency use because they are relatively simple, reliable, and easy to start and operate under cold conditions. Special precautions must be taken with the fire and bilge pump to see that the suction strainers are kept clean. Clogged suction strainers and the presence of foreign matter in the water chest suction and discharge

valves are the most frequent causes of trouble in the liquid end of the fire and bilge pump.

The EMERGENCY or AUXILIARY FEED PUMP is a direct-acting, simplex, double-acting, high pressure, vertical pump of the type shown in figure 5-12. The pump is operated from the auxiliary steam line. It is used for filling idle boilers, for transferring reserve feed water, for applying pressure to boilers undergoing hydrostatic test, and in some cases for regular boiler feed service for in-port (auxiliary) steaming. This pump does not have sufficient capacity for high firing rates, and its use is therefore limited to emergency or auxiliary service.

EDUCTORS

The pumps discussed so far in this chapter have been electrical or mechanical driven. Eductors, like other types of jet pumps, have no moving parts. They are actuated by water, under a designed or set pressure, and are used to pump large volumes of water.

On modern ships, eductors have replaced fire and bilge pumps as the primary means of pumping large volumes of water overboard, in applications such as pumping bilges, deballasting, and dewatering compartments. By use of eductors, centrifugal fire pumps can, indirectly, serve as drainage pumps without the risk of becoming fouled with debris from the bilges. The centrifugal pumps pressurize the firemain, and water from the firemain is used to actuate the eductors. On modern combatant ships the eductors have a much larger pumping capacity than fire and bilge pumps. They are installed as part of the piping in the drainage system and are flanged to permit easy removal and disassembly when repairs are necessary.

CHAPTER 6

PUMP OPERATION AND MAINTENANCE

Chapter 5 contained information on types of pumps, their construction, and principles of operation. Most of the information was on the two most common types of pumps, centrifugal and reciprocating. This chapter gives general information on the operation and maintenance of centrifugal and reciprocating pumps and safety precautions applicable to pumps installed on Navy ships. As an MM3 or MM2, you must know a great deal about the operation and maintenance of engineroom pumps. You may find it helpful to review this subject in Fireman, NAVPERS 10520-D, and chapter 9470 of the Naval Ships Technical Manual.

The operation and safety pertaining to pumps should be in accordance with NAVSHIPS Technical Manual and/or the instructions posted on or near each individual pump. All maintenance actions, tests, and inspections should be accomplished in accordance with the Planned Maintenance Subsystem. Figure 6-1 (Maintenance Index Page) shows the minimum maintenance requirements for a Turbine Driven Main Lube Oil Pump.

CENTRIFUGAL PUMPS

This section contains information about centrifugal pumps that you should know, such as: (1) how they are constructed, (2) how to operate them, (3) how to take care of them, and (4) what precautions must be observed when you operate them.

OPERATING INSTRUCTIONS

The operating instructions for centrifugal pumps vary somewhat from one pump to another. Before attempting to operate any pump, therefore, you should read the posted operating instructions, read the valve labels, and check the piping markings.

The posted instructions for starting and operating a centrifugal pump will probably read something like this:

1. Check the lube oil level in the sump tank or bearing housing. Fill the oil cups or reservoirs, if fitted. Rotate the handle of the lube oil filter before starting the pump, and at least once during each watch.
2. Lubricate the linkage and slides on the speed limiting governor. If a gravity-feed oil cup is provided for the end bearing of the governor spindle, lift the snap tip of the needle valve to a vertical position; and check to be sure that oil is being fed at the proper rate—about 5 to 10 drops per minute, or as recommended by the manufacturer's technical manual.
3. Open the pump suction valve.
4. Check the suction pressure.
5. Make sure that the recirculating valve (if installed) is locked in the OPEN position.
6. Open the vents on the pump end.
7. When the vents on the pump end discharge solid streams of water, close them.
8. Open all drains on the steam end.
9. Open the turbine exhaust valve.
10. Open the bypass around the constant pressure pump governor (if fitted).
11. Crack open the turbine throttle (or start the motor).
12. Close the drains when steam blows through them.
13. Increase the throttle opening and run the pump fast enough so that the lube oil will begin to circulate. Make sure that the packing gland leak-off is adequate.
14. Make sure that the speed limiting governor is free and operable. If an overspeed trip is installed, trip it by hand and reset it.
15. Continue to run the pump at moderate speed until the oil temperature reaches 100° F. Be sure to keep the pump running fast enough to maintain adequate discharge; if the discharge

System, Subsystem, or Component	Reference Publications
Turbine Driven Main Lube Oil Pump	

Bureau Card Control No.					Maintenance Requirement	M.R. No	Rate Req'd.	Man Hours	Related Maintenance
MM	ZVVFPJ4	95	4006	W	1. Sample and inspect lube oil. 2. Lubricate speed limiting governor. 3. Turn idle pump by hand; if free, operate by power.	W-1	FN	0.5	None
MM	ZZ1FRP6	95	7768	M	1. Test the speed limiting governor.	M-1	MM2 FN	0.1 0.1	None
MM	ZZ2FPJ4	84	4839	Q	1. Clean sump. 2. Clean lube oil filter. 3. Renew oil.	Q-1	MM2 FN	2.0 2.0	None
MM	ZVVFPJ4	95	4369	Q	1. Sound and tighten foundation bolts. 2. Lubricate flexible coupling.	Q-2	MM3	0.3	None
MM	ZZPFTRO	94	5422	Q	1. Measure turbine thrust clearance.	Q-3	MM2 FN	0.3 0.3	None
MM	ZZFFVA1	84	0851	Q	1. Test combination exhaust and relief valve. 2. Test lube oil relief valve.	Q-4	MM2 FN	0.2 0.2	None
MM	ZZ1FRP5	A5	4854	Q	1. Clean and inspect pump pressure regulator.	Q-5	MM2	2.0	None
MM	ZVVFPJ4	A5	6042	A	1. Inspect shaft journals, thrust collar, and bearings for condition; measure bearing clearance. 2. Inspect and clean steam strainer.	A-1	MM2 FN	3.3 3.3	M-1 Q-1 Q-3
MM	ZXFFCW4	95	4370	A	1. Renew stuffing box packing. 2. Inspect flexible coupling.	A-2	MM2	2.0	Q-2
MM	ZX6FPJ4	84	6044	A	1. By operational test, inspect internal parts for wear.	A-3	MM2	0.3	None
MM	ZZPFTRO	95	6045	C	1. Inspect carbon packing for wear. 2. Inspect turbine exterior.	C-1	MM2 FN	3.0 3.0	None

MAINTENANCE INDEX PAGE
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Figure 6-1.—PMS, Maintenance Index Page.

pressure is too low, the pump packing will not be lubricated properly.

16. When the lube oil temperature reaches 100° F, cut in the cooling water to the oil cooler. Regulate the flow of cooling water to suit operating conditions. Be sure that all air is vented from the waterside of the cooler.

17. When ordered to cut in the pump, close the constant pressure governor bypass valve and open the throttle valve all the way. Bring the discharge pressure up to the required line pressure by putting tension on the constant pressure governor spring, and slowly open the discharge valve.

If the pump fails to build up pressure, notify the petty officer of the engineroom watch. If the pressure goes too high, open bypass and use manual control until another pump has been started, and is on the line. Then secure the malfunctioning pump and correct the trouble.

Instructions for stopping and securing a centrifugal pump will, in general, read something like this:

1. Release tension on the constant pressure governor spring.
2. Close the throttle valve (OR stop the motor.)
3. Close the exhaust valve.
4. Open the turbine drains.
5. Close the pump discharge valve.
6. Close the suction valve.
7. Close the drains, after the turbine is completely drained.
8. Secure the cooling water to the lube oil cooler.

OPERATING TROUBLES

Some of the operating troubles which you may have to deal with in centrifugal pumps, together with the probable causes, are given in the following paragraphs.

If a centrifugal pump DOES NOT DELIVER ANY LIQUID, the trouble may be caused by (1) insufficient priming; (2) insufficient speed of the pump; (3) excessive discharge pressure, such as might be caused by a partially closed valve or some other obstruction in the discharge line; (4) excessive suction lift; (5) clogged impeller passages; (6) the wrong direction of rotation; (7) clogged suction screen (if used); (8) ruptured suction line; or (9) loss of suction pressure.

If a centrifugal pump delivers some liquid but operates at INSUFFICIENT CAPACITY, the trouble may be caused by (1) air leakage into the suction line; (2) air leakage into the stuffing boxes, in pumps operating at less than atmospheric pressure; (3) insufficient speed of the pump; (4) excessive suction lift; (5) insufficient liquid on the suction side; (6) clogged impeller passages; (7) excessive discharge pressure; or (8) mechanical defects such as worn wearing rings, impellers, stuffing box packing, or sleeves.

If a pump DOES NOT DEVELOP ENOUGH DISCHARGE PRESSURE, the trouble may be caused by (1) insufficient speed of the pump; (2) air or gas in the liquid being pumped ; or (3) mechanical defects such as worn wearing rings, impellers, stuffing box packing, or sleeves.

If a pump WORKS FOR A WHILE AND THEN FAILS TO DELIVER LIQUID, the trouble may be caused by (1) air leakage in the suction line; (2) air leakage in the stuffing boxes; (3) clogged water seal passages; (4) insufficient liquid on the suction side; or (5) excessive heat in the liquid being pumped.

If a motor-driven centrifugal pump TAKES TOO MUCH POWER, the trouble will probably be indicated by overheating of the motor. The basic cause of the difficulty may be (1) operation of the pump at excess capacity and insufficient discharge pressure; (2) excessively high viscosity or specific gravity of the liquid being pumped; or (3) misalignment, a bent shaft, excessively tight stuffing box packing, worn wearing rings, or other mechanical defects.

VIBRATION of a centrifugal pump is often caused by (1) misalignment; (2) a bent shaft; (3) a clogged, eroded, or otherwise unbalanced impeller; or (4) lack of rigidity in the foundation. Insufficient suction pressure may also cause vibration, as well as NOISY OPERATION and FLUCTUATING DISCHARGE PRESSURE, particularly in pumps handling hot or volatile liquids.

If the pump fails to build up pressure when the discharge valve is opened and the pump speed increased, proceed as follows:

1. Secure the pump.

2. See that the pump is primed and that all air is expelled through the air cocks on the pump casing.

3. See that all valves on the pump suction line are open.

4. Start the pump again. If the discharge pressure is not normal when the pump is up to its proper speed, the suction line may be clogged, or an impeller broken. It is also possible that

air is being drawn into the suction line or into the casing. If any of these conditions exist, stop the pump, try to find the source of the trouble, and correct it, if possible.

MAINTENANCE OF CENTRIFUGAL PUMPS

Some of the information which you must have in order to give proper care and maintenance to centrifugal pumps is given in this section. For further details, and for specific information on any one pump, you should consult the applicable Maintenance Requirement Cards (MRC), Naval Ships Technical Manual, and the appropriate manufacturer's technical manuals. Before attempting to repair a pump, you should assemble the pump history and all pertinent drawings and dimensional data.

LUBRICATION is essential for the proper operation of centrifugal pumps, and inadequate lubrication is a primary cause of pump failure. The supply of oil to the bearings must be checked frequently during each watch. Grease cups and bearing housings must be kept filled with lubricant, and free of water or other foreign matter. Lubricating oil should be changed whenever it foams excessively, becomes emulsified, or contains dirt or sludge.

Repacking Pumps

Lubrication of the pump packing is extremely important. The quickest way to wear out the packing is to forget to open the water piping to the seals or stuffing boxes. If the packing is allowed to dry out, it will score the shaft. When you are operating a centrifugal pump, be sure that there is always a slight trickle of water coming out of the stuffing box or seal.

How often the packing in a centrifugal pump should be renewed depends on several factors. The type of pump, condition of the shaft sleeve, and hours in use, are only a few of the factors that determine the length of service of packing. A fresh water service pump may run for several months with no maintenance required, while a brine overboard pump may have to be repacked about once a month in order for it to perform satisfactorily.

To ensure the longest possible service from pump packing, make certain that the shaft or sleeve is smooth when packing is removed from a gland. Rapid wear of the packing may be caused by roughness of the shaft sleeve or shaft. If the shaft is rough, it should be sent to the shop for a finishing cut to smooth the surface. If it is very rough, or has deep ridges in it, it will have to be renewed. It is absolutely necessary to use the correct packing. Navy packing is identified by symbol numbers as explained in chapter 7 of this training manual. To find the right packing for a particular pump, check the Maintenance Requirement Card (MRC) for the pump. The MRC lists the symbol numbers and the size and number of rings required. When cutting the packing rings make the ends square, not beveled, and cut each ring so that the ends will just touch when installed on the shaft. Insert the packing with the ends staggered at 90° intervals.

When replacing packing see that there is a uniform thickness around the shaft sleeves. An excess of packing on one side of the shaft will deflect the shaft, and frequently cause it to break.

The box should be packed loosely and the packing gland set up lightly, allowing a liberal leaking for stuffing boxes subjected to pressure above atmospheric. Then, with the pump in operation, the gland should be tightened in small increments, with several hours between tightenings, to compress the packing gradually, thereby avoiding excessive heat and scoring of the shaft or shaft sleeve. Remember that a certain amount of leakage is necessary for lubrication and cooling.

After the packing has been compressed, it will usually be necessary to add more packing. The water supply to the packing seal should be examined frequently during each watch to ensure that it is clear.

Care of Lantern Rings, Sleeves, and Flingers

Where a stuffing box is fitted with a lantern ring, be sure to replace the packing beyond the lantern ring at the bottom of the stuffing box, and see that the sealing water connection to the lantern ring is not blanked off by the packing. (See fig. 5-5.) Sleeves fitted at the packing on the pump shafts must always be tight. These sleeves are usually made secure by shrinking or keying them to the shaft. Care must be taken to see that water does not leak between the shaft and the shaft sleeves.

Water flingers fitted on the shaft outboard of the stuffing box glands, to prevent leakage from the stuffing box following along the shaft and entering the bearing housings, must also be kept

tight. If the flingers are fitted on the shaft sleeves instead of on the shaft, no water must leak under the sleeves.

Renewing Shaft Sleeves

In some pumps, the shaft sleeve is pressed onto the shaft tightly by means of a hydraulic press, and the old sleeve must be machined off in a lathe before a new one can be installed. On other centrifugal pumps, the shaft sleeve is a snug slip-on fit, butted up against a shoulder on the shaft and held securely in place with a nut. On some small pumps, new sleeves can be installed by removing the water end casing impeller, and old shaft sleeves. New sleeves are carried as repair parts or they can be made in the machine shop. On large pumps, the sleeves are usually pressed on; these pumps must be disassembled, and taken to the machine shop, a repair ship, or a navy yard, to have the old sleeve machined off and a new one pressed on.

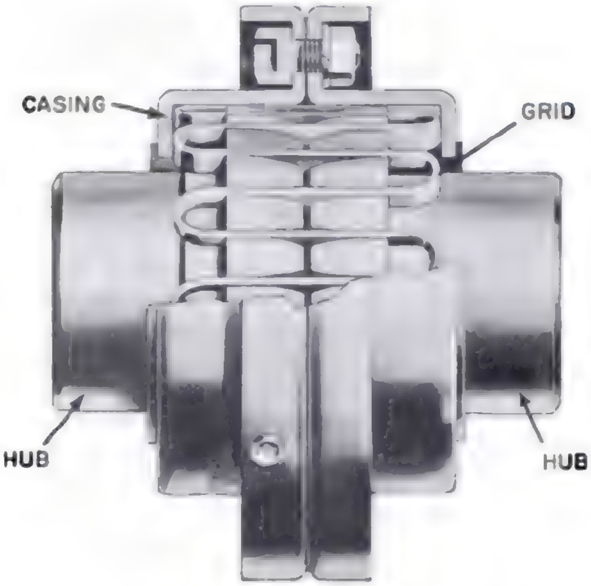
In order to prevent water leakage between the shaft and the sleeve, some sleeves are packed, while some have "0" rings between the shaft and the abutting shoulder. For detailed information, consult the appropriate PMS material, manufacturer's technical manual, or applicable blueprints.

SHAFT ALIGNMENT must be checked frequently. If the shafts are out of line, the unit must be realigned in order to prevent shaft breakage and damage to bearings, pump casing wearing rings, and throat bushings. Shaft alignment should be checked with all piping in place.

Alignment of Shafting and Couplings

When the driving unit is connected to the pump by means of a FLEXIBLE COUPLING, remember that flexible couplings (shown in fig. 6-2) are intended to take care of only slight misalignment. Misalignment should never exceed the amount specified by the pump manufacturer. If the misalignment is excessive, the coupling parts are subjected to severe punishment, necessitating frequent renewal of pins, bushings, and bearings.

When the driving unit is connected or coupled, to the pump by means of a FLANGE COUPLING, frequent realignment of the shafting is necessary. Each pump shaft must be kept in proper alignment with the shaft of the driving unit. Misalignments are indicated by such things as abnormal temperatures, abnormal noises, and worn bearings or bushings.



38.88
Figure 6-2.—Grid type flexible coupling.

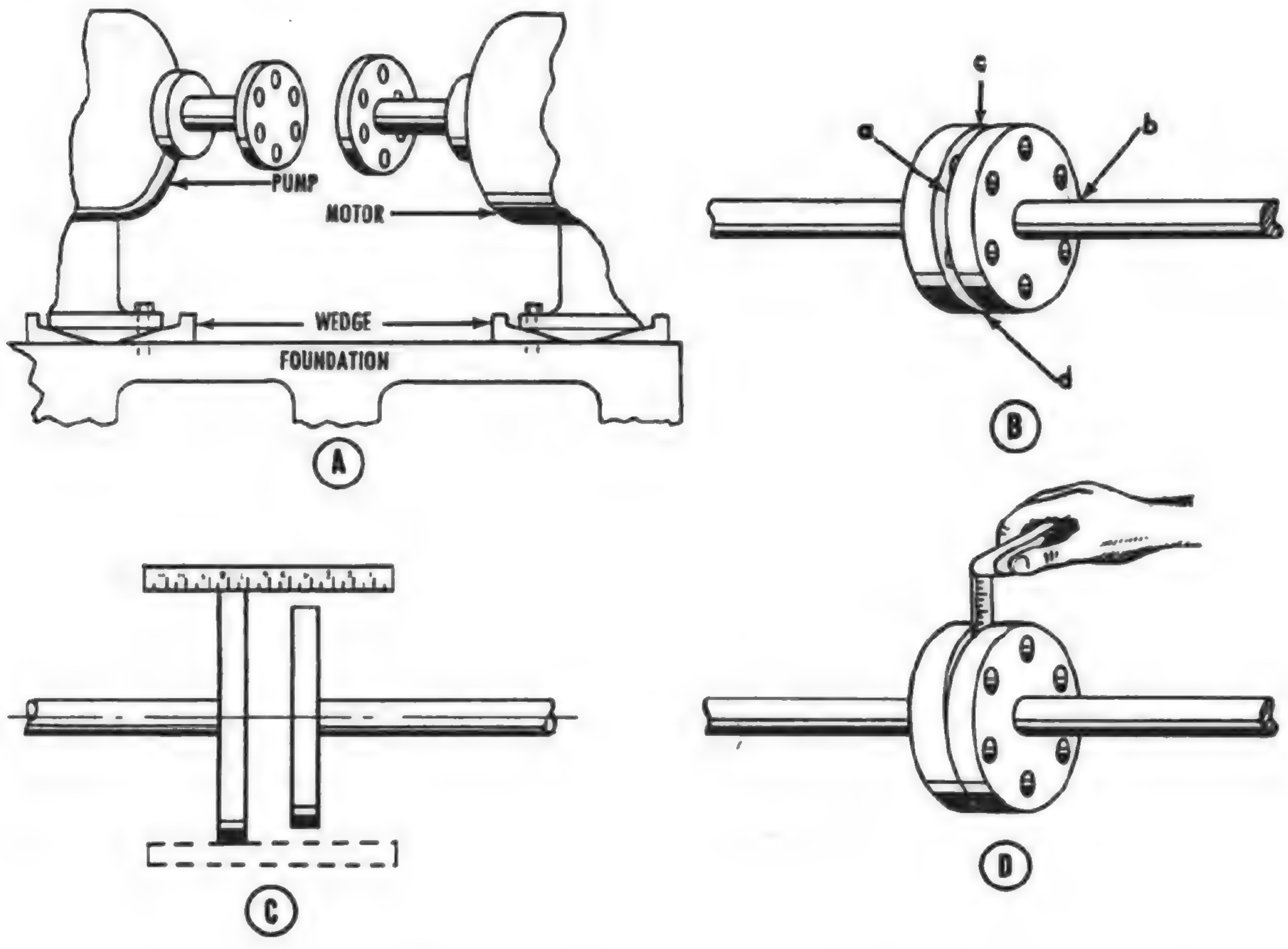
Wedges or shims, are placed under the bases of both the driven and driving units (as illustrated in part A of fig. 6-3) to facilitate alignment when the machinery is installed. Jacking screws may also be used to level the units. When the pump or driving unit, or both, have to be shifted sidewise to align the couplings, side brackets are welded in convenient spots on the foundations, and large setscrews are used to shift the units sidewise or endwise. When the wedges or other packings have been adjusted so that the outside diameters and faces of the coupling flanges run true as they are manually revolved, the chocks are fastened, the units securely bolted to the foundation, and the coupling flanges bolted together.

These ALIGNMENTS MUST BE CHECKED from time to time, and misalignments promptly corrected. There are three methods employed in general practice, for checking the alignments:

1. With the use of a 6-inch scale.
2. With the use of a thickness gage.
3. With the use of a dial indicator.

Some types of installations, of course, call for special methods of handling.

When USING A 6-INCH SCALE to check alignments, check the distance between the faces



47.49
Figure 6-3.—Alignment of flange coupling: A. Leveling the unit. B. Aligning coupling faces. C. Aligning flange diameters. D. Checking with feelers.

of the coupling flanges at 90° intervals. Find the distances between the faces at point a (part B of fig. 6-3), point b (on the opposite side), point c, and point d (opposite point c). This will indicate whether the coupling faces are parallel with each other if they are not parallel, adjust the driving unit or the pump or both, with shims until the couplings check true. While the distances are being measured the outside diameters of the coupling flanges must be kept in line. To do this, place the scale across the two flanges, as shown in part C of figure 6-3. If the flanges do not line up, raise or lower one of the units with shims. Then, if necessary, shift them sidewise by means of the jacks welded on the foundation. The scale should be used (as shown in part C of fig. 6-3) at intervals of 90°, as was done in checking between the flange faces (part B of fig. 6-3).

When USING A THICKNESS GAGE to check alignments, the procedure followed is similar to that employed with a scale. When the outside diameters of the coupling flanges are not the same, use a scale on the surface of the larger flange, then use "feelers" between the surface of the smaller flange and the edge of the scale. The distance between the coupling flanges may be checked with a thickness gage (as shown in part D of fig. 6-3), when the space is narrow. Wider spaces are checked with the use of a piece of square key-stock and a thickness gage. The couplings should be revolved one at a time, and checked at 90° intervals. If the faces are not

true, the shaft has been sprung. Many times the shafts must be removed and sent to the ship's machine shop for reworking.

When USING A DIAL INDICATOR to check alignments, clamp the indicator to one coupling flange, then revolve the opposite coupling. If no variation is shown on the indicator, the coupling is running true. By revolving the coupling with an indicator clamped to it, while the opposite coupling remains still, the degree to which the coupling centers are out of line will be shown. An adjustment (necessitating the loosening of bolts at unit bases) must be made, and the alignment checked again. When alignment is true, secure the dowels at the unit bases, and insert and fasten the coupling bolts. Dial indicators should be used wherever possible in aligning a coupling.

Shaft alignment should be checked whenever the pump is opened up, and whenever a noticeable vibration is observed. If it is found that shafts are out of line or inclined at an angle to each other, alignment of the unit should be undertaken in order to avoid shaft breakages and renewal of bearings, pump casing wearing rings, and throat bushings.

Measuring Bearing Clearances

In a centrifugal pump installation, fitted with an internal water-lubricated bearing inside the pump casing (such as condensate pumps), an adequate supply of clean water, for lubricating and cooling, must be supplied to the bearing. Several types of materials which have been used for internal water lubricated bearings are as follows:

1. Laminated phenolic material grade FBM (fabric base bakelite or Micarta).
2. High lead content bronze.
3. Graphited bronze.
4. Lignum vitae bearings are also satisfactory.

However, because these bearings are hard to install, their use is NOT recommended, except in an emergency.

The condition of all types of internal water-lubricated bearings should be checked frequently to guard against excessive wear which results in misalignment and possibly shaft failure.

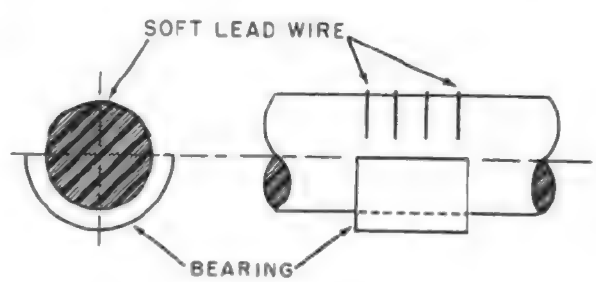
As far as oil-lubricated sleeve or shell-type bearings are concerned, the bearing clearances should be measured in accordance with the Planned Maintenance Subsystem. Maintain the clearances, within the limits shown on the manufacturer's plans. If such plans are not available, follow the instructions outlined in chapter 9400 of the Naval Ships Technical Manual.

When measuring the clearance of a bearing by taking leads, the following procedure is used:

1. Remove the upper half of the bearing.
2. Lay several lengths of soft lead wire circumferentially on the journal. Do not use hard fuse wire.
3. Replace the upper half of the bearing and set up on all bearing nuts. Mark the position of each one.
4. Remove the top half of the bearing; examine, and measure the thickness of the leads with a micrometer.

The best method of placing the leads on the journal is shown in figure 6-4. Leads should not be used which are heavier than required for the clearance to be measured. When taking leads, see that all bolts, bolt holes, bearing surfaces, liners (if used), and butting faces of the shells are free from foreign matter. When the leads have been properly placed and the bearing assembled, the nuts should be run down to bring the shells solidly against the liners (if used), or to bring the metal-to-metal butting faces together. (Do not apply an additional force to the nuts because it may result in deforming the threads or straining the metal of the bolts.) When set up, the position of the bearing nuts should be marked so that they may be again tightened the same amount after the leads have been removed.

When the leads are removed from the journal one end of each lead should be pinned to a piece of paper. The leads should be spaced the same distance apart and arranged in the same order



47.50
Figure 6-4.—Taking leads.

as they were on the journal. If the lead is found to be squeezed out evenly along its entire length, the clearance is uniform. To determine the bearing clearance, measure each lead at, or near its mid-point. The average thickness will indicate the bearing clearance, provided there is no great variation in the thickness of the individuals leads. In addition, the thickness of each lead should be carefully measured at several places, with a micrometer, along the length of the wire. Leads which vary in thickness indicate an uneven bearing surface. Such bearings should be refitted to give uniform clearance.

Fitting and Spotting-In of Bearings

To fit a bearing to its journal, coat the journal with a very thin layer of Prussian blue. Lay one of the bearing halves on the journal and rotate it back and forth slightly. Remove the bearing half and examine the surfaces for high spots. The high spots are located in the area where the coloring compound has adhered to the bearing surfaces. These spots must be scraped (do not let tool chatter on bearing surface) to produce a smooth and even contact surface. Continue this process until the Prussian blue is uniformly distributed over the bearing surface, and covers such an area that practically all of the surface is in contact with the journal. With large bearings or those that are not easily accessible, use a mandrel the exact size of the journal. During the finishing operations, you should, as a final check, spot the bearing to the journal. After the bearing has been spotted in, take leads to determine if the bearing clearance is satisfactory.

When scraping-in a bearing, care must be taken that the lining is concentric with the shell. (If the concentricity of a bearing is lost, the pump shaft may become misaligned. This will cause unequal loads on the bearings along the shaft, and is also likely to destroy the clearances between the casing wearing rings and the impeller wearing rings.)

With very small bearings the amount of clearance is often determined by "feel." These bearings should be fitted as previously described and assembled on their journals with the bearing nuts set up hard. If the clearance is correct, there will be only the slightest indication of play between the bearing and its journal, and the journal will revolve easily.

Renewal of Wearing Rings

The clearance between the impeller wearing ring and the casing wearing ring (fig. 6-5) must be maintained as shown in the manufacturer's plans. When clearances exceed the specified figures, the wearing rings must be replaced. On most ships, this job can be done by the ship's force but it requires the complete disassembly of the pump. All necessary information on disassembly of the unit, dimensions of the wearing rings, and reassembly of the pump is specified by PMS or can be found in the manufacturer's technical manual.

In deciding whether the wearing rings need renewing, the capacity of the pump and the discharge pressure of the pump must be taken into consideration. On low pressure pumps, the wearing ring diametral clearance may be 0.015 to 0.030 inch more than the designed amount without any appreciable effect on the pump's capacity. For pumps having a discharge pressure up to 75 psi, a wear of 0.030 to 0.050 inch is permissible.

The percentage of capacity loss, with a 0.030 inch wearing ring clearance in excess of standard, may be large with a small pump, but comparatively small with a large pump. For high pressure boiler feed pumps, the effect of increased wearing ring clearance is readily noticeable in the efficiency and maximum capacity of the pump. For high pressure pumps the wearing rings should be renewed when the

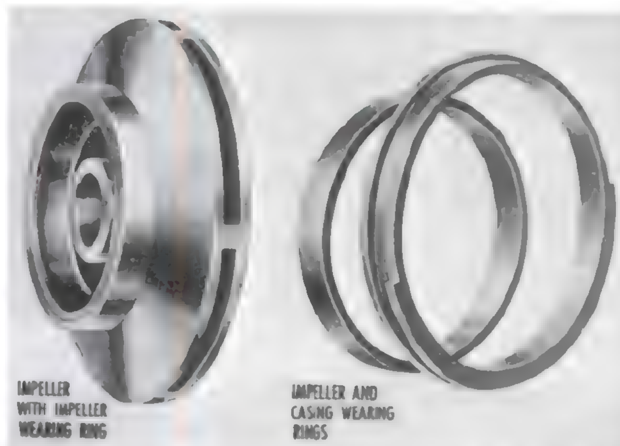


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Figure 6-5. —Impeller, impeller wearing ring, and casing wearing ring for a centrifugal pump.

clearance shown on the manufacturer's plans is exceeded by 100 percent. It is usually not considered necessary to renew wearing rings unless the wear is at least 0.015 inch. If a pump has to be disassembled because of some internal trouble, the wearing rings should be checked for clearance. Measure the outside diameter of the impeller wearing ring with an outside micrometer, and the inside diameter of the casing wearing ring with an inside micrometer; the difference between the two diameters will be the actual wearing ring diametral clearance. By checking the actual wearing ring clearance with the maximum allowable clearance, it can be decided whether to renew the rings before reassembling the pump. The applicable Maintenance Requirement Cards are ready available source of information on proper clearances.

The amount of work involved indisassembling the pump, the length of time the pump can be out of commission without affecting the ship, and whether or not a repair ship or other repair activity will be involved are some of the factors that have to be taken into consideration when determining whether to renew wearing rings.

For most small pumps, wearing rings are carried aboard as part of the ship's repair parts allowance. These may need only a slight amount of machining before they can be installed. For some pumps, such as main condensate, and main feed booster pumps, spare rotors are carried aboard. The new rotor can be installed and the old rotor sent to a repair activity for overhaul. Overhauling a rotor includes renewing the wearing rings, bearings, and the shaft packing sleeve.

RECIPROCATING PUMPS

As a Machinist's Mate, you will be required to operate and maintain reciprocating pumps. This type of pump was introduced in Fireman, NAVPERS 10520-D. Additional information is provided in the sections which follow.

OPERATION OF RECIPROCATING PUMPS

Procedures for the operation of the general service pump, are in general, the same as for any other reciprocating pump. With the general service pump, however, special precautions must be taken to see that the suction strainers are kept clean. Clogged suction strainers and the presence of foreign matter in the water chest suction and discharge valves are the most frequent causes of trouble in the liquid end of the general service pump.

Operating and Securing Instructions

1. Check to be sure that the steam cylinder and steam chest drain valves are open. (They should always be opened when the pump is shut down.)

2. Oil the pins and bushings of the valve operating gear.

3. Open the water end suction and discharge valves.

4. Open the steam end exhaust valve.

5. Crack open the throttle valve. Warm up the steam end slowly.

6. When the cylinder and chest are free of water, close the drain valves.

7. Bring the pump up to the desired speed or discharge pressure by slowly opening the throttle valve.

The following steps are generally used in securing a reciprocating pump:

1. Close the throttle valve.
2. Open the steam cylinder and chest drain valves.
3. Close the exhaust valve.
4. Close the water end suction and discharge valves.

Operating Troubles

From time to time you are likely to have some operating troubles with reciprocating pumps. The most common causes of trouble, together with their symptoms and remedies, are described here.

Lack of proper suction will cause jerky or irregular operation of the pump, or it may cause the pump to race without any appreciable increase in discharge pressure. Loss of suction may be caused by a number of different conditions, including:

1. Obstructions in the suction line.
2. Loss of suction head, which causes the pump to become vaporbound.

3. Air in the system, which causes the pump to become airbound.

Obstructions in the suction line frequently cause trouble in fire and bilge pumps. Be sure that the suction line is clear and that all stop or check valves in the line are open. Clean the suction line strainer and the bilge strainer.

A pump can lose suction by becoming airbound—that is, having air trapped in the system. The remedy for this condition is to open the aircocks and vents on the liquid end valve chest; leave them open until water flows out.

Insufficient prime often causes loss of suction in pumps which have a considerable suction lift. The fire and bilge pump can be primed from the sea by opening the sea suction valve for a short time.

Worn packing on the plunger or damaged suction or discharge valves in the liquid end may cause the pump to race without an appreciable increase in discharge pressure. It is hard to distinguish this kind of trouble from the troubles caused by loss of suction, since the general symptoms are very similar. However, if you suspect that the plunger packing is worn or that the liquid end valves are damaged, you should stop the pump as soon as possible and locate and correct the trouble.

Groaning in the steam end of the pump may indicate that the piston rod packing is too tight, that the piston or a piston ring is broken, that rust has formed in the cylinder, or that the steam cylinder is out of alignment. The pump should be secured so that the difficulty may be found and corrected.

Groaning in the liquid end of the pump is generally due to excessively tight packing or broken or damaged follower plate or other broken parts. Stop the pump and investigate.

Knocking in the steam end of the pump may be caused by too long a stroke, by water in the steam cylinder, by loose pistons or piston rings, or by some difficulty in the piston-type valve gear. The pump should be stopped at once so that the trouble may be found and corrected.

Proper adjustment of the length of stroke is extremely important. If the stroke is too long, the steam piston will hit against the cylinder heads and make a heavy, metallic knocking sound. When the stroke is too short, the pilot valve may block the ports sufficiently to interfere with the admission of steam into the main valve and this may cause the pump to stop. In addition, a short stroke causes shoulders to be worn in the cylinder; and when the stroke is lengthened, these shoulders may cause the piston rings to break. Improper length of stroke, whether too short or too long, may cause great damage to the pump. To adjust the pump stroke, throttle down the pump, and adjust the stroke as necessary.

MAINTENANCE OF RECIPROCATING PUMPS

Reciprocating pumps require routine maintenance and, upon occasion, some repair work. Pumps are so widely used for various services in the Navy that it is necessary to consult the manufacturer's technical manual for detail concerning the repair of a specific unit. Routine maintenance, however, is performed in accordance with PMS requirements. For additional information, check chapter 9470 Naval Ships Technical Manual.

Before repairing or examining a pump, assemble the Maintenance Requirement Cards, all the pertinent blueprints, drawings, and available data. These drawings and data will give you the required clearances, tools to be used, measurements, information regarding materials to be used, and other important data. In addition, you should have the complete history of the pump being repaired, so that you will know what has been done previously, when repairs were made, and what kind of trouble has been encountered with this particular pump.

Whenever reciprocating pumps are opened for repairs, micrometer or caliper measurements should be taken of the main cylinders and the valve chest cylinders. These measurements are made on the fore and aft and athwartships diameters at the top, middle, and bottom. The results should be recorded with accompanying remarks or a diagrammatic sketch showing the measurements obtained and the date on which they were made.

Remember that the steam end of a reciprocating pump should NOT be dismantled until a thorough check reveals that the water end is satisfactory. Most reciprocating pump troubles, however, result from fouled water cylinders, worn valves, or from faulty conditions in the pipe connections external to the pump.

Adjustment of Stroke

In order for a steam-driven reciprocating pump to operate properly, the steam piston

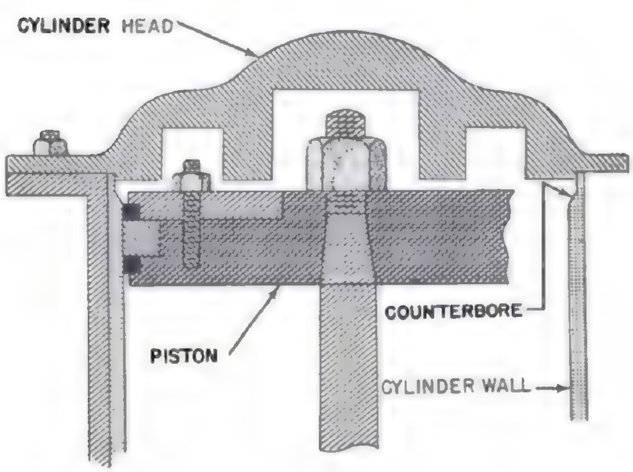
must travel a little beyond counterbore (fig. 6-6); this means that the pump must operate with a full stroke. A full stroke will result in more even wear throughout the cylinder.

The length of the stroke is adjusted by moving the two adjustable tappet collars on the threaded portion of the valve rod link. The tappet moves between the tappet collars as the lever is moved by the action of the piston rod.

To shorten the stroke of the pump, turn the tappet collar in the direction that moves it toward the tappet. To lengthen the stroke of the pump, turn the tappet collar in the direction that moves it away from the tappet. Once the tappet collars have been set properly, they should be left alone. If it becomes necessary to adjust the tappet collars frequently while the pump is operating, the pump should be stopped and disassembled as soon as possible. The trouble may be in the operating linkage, the auxiliary piston valve, or the main piston valve.

Properly adjusted tappet collars will ensure a full stroke for the various pump loads and speeds. Refer to manufacturers' drawings and technical manuals of detailed information as to the method to be followed for specific types of valve gear. The following method may be used for a general guide if the appropriate information is not available.

Place the steam piston and auxiliary piston valve on the center or half stroke. Then move each tappet collar so that it will be one-half the width of the steam port away from the tappet.



38.101
Figure 6-6.—Steam piston at upper end of stroke.

Next start the pump. If the stroke is too short, move the tappet collars further apart. If the stroke is too long, move the tappet collars closer together. Make certain that the tappets are moved an equal amount or the stroke will be longer on one end than on the other. When final adjustment has been made, lock the tappet collars securely in place.

Run the pump slowly, with the throttle cracked, against little or no pressure, and with the cushioning valves wide open. The piston should be striking on the cylinder heads (if it does not, there is friction at some point). Close down on the cushioning valves until the pump is running at full stroke and with smooth reversal and no striking. If it is impossible to obtain smoothness of reversal, it may be necessary to adjust the tappet collars.

In figure 6-7 the steam piston is shown beginning the up stroke. Both valves are in the upper position, thereby admitting high pressure steam through the lower steam inlet port to the underside of the steam piston, and permitting steam above the piston to escape through the exhaust port.

When the steam piston reaches the top of the stroke the lever and tappet linkage move the pilot (auxiliary piston valve) down, opening port A to the annual exhaust space above the center of the auxiliary and main piston valve. See figure 6-7. Opening port A releases pressure in space B, below the main piston valve, and permits the unbalanced higher pressure in space C to force the main piston valve down. The small size of the equalizing port in the main piston valve prevents the escape of any appreciable amount of high pressure steam into space B. The pilot valve blanks off the upper port, preventing the escape of high pressure steam from space C, even after the downward movement of the main piston valve uncovers port C, and thereby ensures complete movement of the piston valve to its lower position.

At the end of its travel, the main piston valve cushions itself when it blanks off the port to space A, trapping dead steam which cannot readily escape through the small equalizing port in the valve. The initial condition of steam balance is reestablished by means of this equalizing port. The previously described movements are repeated on the opposite end of the stroke.

The force which actuates the main piston valve is determined by the difference in the rate of flow of steam through port A, which

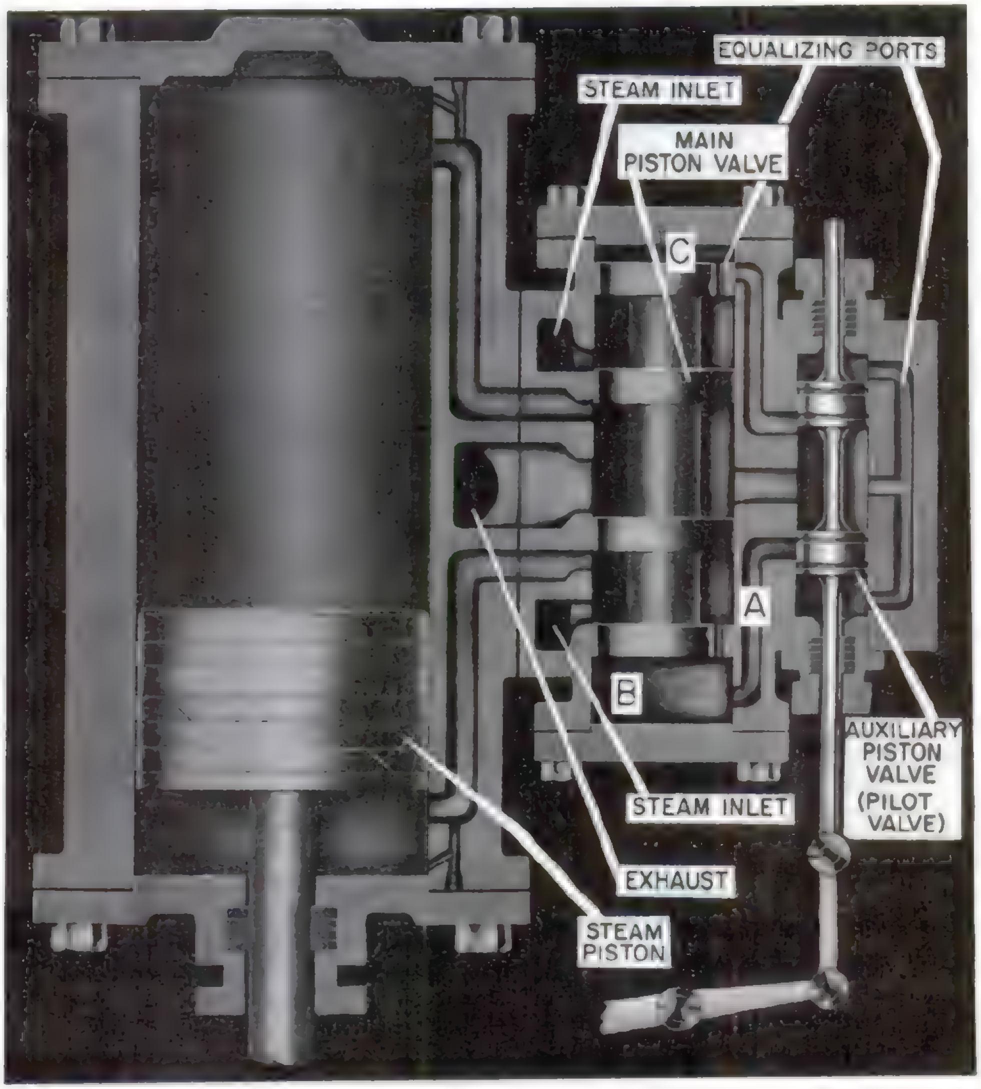


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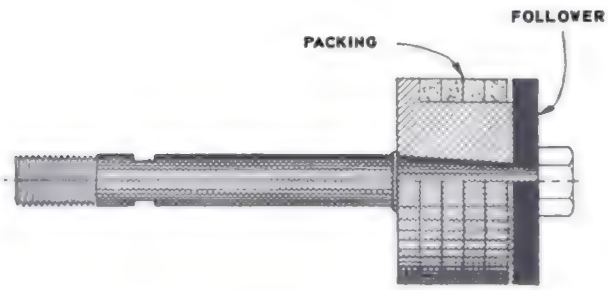
Figure 6-7.—Steam end assembly for a reciprocating pump.

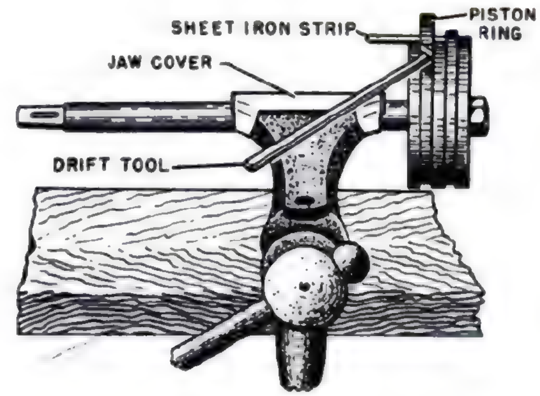
is 1/4 inch in diameter, and through the 1/16-inch equalizing port drilled through the outside collars of the main piston valve. Except when the main piston valve is actually in motion, it is in complete balance, both axially and circumferentially, so that the friction between the sliding surfaces is the only force restricting its travel. The equalizing port, which connects the outer ends of the auxiliary piston valve cylinder, is essential to permit free movement of the auxiliary piston valve. Light packing will suffice for the pilot valve actuating rod, since only auxiliary exhaust pressures must be held.

Care of Pistons and Packing

Pistons in the waterend of pumps (fig. 6-8) are generally constructed of bronze and are of the body and follower type. The piston itself is not a tight fit, but depends upon several rings of packing to prevent leakage. These rings of packing are placed between a shoulder at one end of the piston and a follower plate at the other end. To renew this packing, close, wire, and tag the water end suction and discharge valves. Remove the bottom water and cylinder head. Then remove the follower and the old packing. Check



47.51
Figure 6-8.—Liquid end piston, rod, packing, and follower.



47.52
Figure 6-9.—Removing piston rings.

the packing chart for the right type and size of packing. If fibrous packing is used, the packing should be soaked in hot water for at least 12 hours before it is cut and installed. The rings should be step-cut, when fitted to the piston. Insert the packing, staggering the ring gaps at 90° intervals.

Replace the follower and, by using a bar, jack the pump over. If the new packing does not bind and there is no groaning in the water end replace the cylinder head. In emergencies fibrous packing can be used without soaking, provided it is cut with sufficient clearance to allow for swelling. Failure to provide ample clearance will cause the pump to groan and may result in a scored cylinder.

Worn or Broken Piston Rings

Troubles in the steam cylinder result mainly from faulty piston rings. Wearing of piston rings can cause a pump to lose power, and even, to stop. If a pump stops, while operating slowly in the middle of a stroke, the trouble may be due to worn rings; secure the pump and examine the condition of the rings and the cylinder. If necessary, renew the piston rings.

Figure 6-9 shows a steam piston assembly of a reciprocating pump. The piston rings are cast iron. If the piston rings are broken or worn or have been poorly fitted so that there is excessive leakage by the piston, new rings must be installed.

To remove a piston ring, hold the piston rod and piston in a vise, as illustrated in figure 6-9. (When doing this, use soft metal covers on the vise jaws to prevent digging into or otherwise abrading the polished surface of the piston rod.) Pry the end of the old ring by means of a thin, pointed drift tool and a strip of sheet iron or an old piece of hacksaw blade, as shown. Continue the prying and add more strips until the ring is raised out of its groove and can be slipped off the piston.

When the rings have been removed, take micrometer measurements of the cylinder or liner to determine the exact diameter. In addition, measure the width of the ring grooves in the piston to determine the width of the new rings. The inside diameter of the new ring can be determined by checking the applicable blueprint or by measuring the inside diameter of an old ring. To take measurements of an old ring, place a piece of chart paper in the gap where the ring is cut, bind the ring so that the ends butt up snugly, and then measure the inside diameter.

When replacing piston rings, first fit the new rings to the cylinder to check the GAP clearance. If the gap clearance is not specified on the blueprint, allow a clearance slightly less than 0.001 of an inch per inch of cylinder diameter. For example, a clearance of 0.007 to 0.008 inch should be allowed for a piston ring of a 10-inch cylinder. If necessary, file the ends until proper clearance is obtained. Check the width of the rings to make sure that they will fit into the grooves properly. You can fit the piston rings by rolling them around the piston grooves. The rings should fit snugly, yet roll freely (fig. 6-10). If they do not roll freely, polish the sides of the rings lightly on fine emery cloth held against a smooth and even surface. Repeat the process until the rings fit properly in their respective grooves. (The ring gaps must be staggered so that they do not fall in one line.)

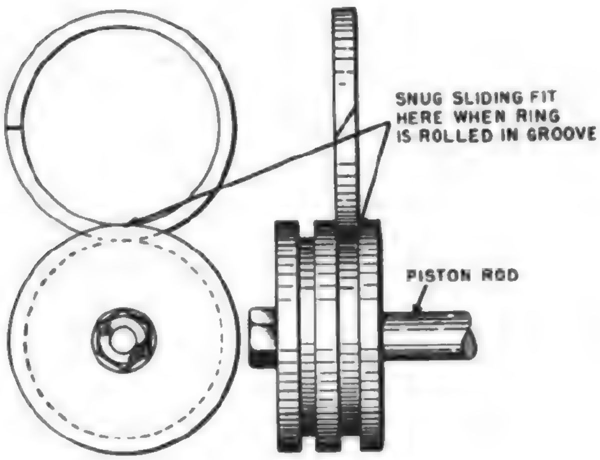


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Figure 6-10.— Fitting piston rings.

Scored Water Cylinder

When a water cylinder becomes scored, it is not always necessary to rebore the cylinder or renew the liner. Slight leakage from wear can usually be corrected by stoning the cylinder liner and renewing the packing. If reboring must be done, consult the tolerances allowed in boring cylinders, given in the manufacturer's technical manual or chapter 9400 of the Naval Ships Technical Manual. Reboring or renewal of the liner should be considered only when the scoring is extensive and rapid wearing of the packing takes place.

Scored Steam Cylinder

Scoring in a steam cylinder, even though of a minor nature, necessitates reboring to prevent steam leakage past the piston. The presence of such leakage is indicated by a dullness and discoloration of the cylinder walls. Once leakage has started, steam will gradually cut away cylinder walls until piston leakage becomes so excessive as to interfere with proper operation of the pump.

Care of Steam Valve Mechanism

The same care must be exercised in fitting the steam valve operating mechanism as is used in fitting the steam piston and cylinder. It is most important that all wear be kept out of the steam valve operating mechanism. Failure to do this will cause the pump to operate in a faulty manner, and perhaps to stick. The pins should be rebushed and renewed as often as necessary. If wear of bushings occurs rapidly, despite careful lubrication, the holes may be bushed with tool steel bushings.

All steam valves must be kept tight because if the pilot valve leaks, the main piston valve will become steambound; that is, the steam pressures in the various passages and parts of the pilot valve chest and the main piston valve chest cylinders will equalize, and the pump will stop. Flat steam valves should be kept true by scraping, and the piston rings of piston valves kept free in the grooves. When scraping flat steam slide valves, the strokes of the scraper should cross, so that the scraper will not chatter on the narrow bridges between the ports; any unevenness will result in steam leakage when the valve is in operation.

As a result of frequent spotting-in of the main piston valve and the pilot valve, the relative size and arrangement of port openings may change owing to irregular coring. A simple method used to check the accuracy of the valve action is to cut paper patterns of the valve and the valve seat faces by laying the paper on the valve and peening with a hammer. Sliding the pattern of the valve over that of the seat will show the exact laps, leads, and port openings, which can be checked with the drawings.

Repairs to Valve Chests, Liners, and Piston Rings

Preventive maintenance of steam valve chests operating under high steam pressures is most important to avoid serious steam cutting and wear. Careful attention to lapping out these early cuts will ensure a tight metal-to-metal fit of the valve chest and steam cylinder.

Prior to making up the metal-to-metal joint, it should be blued and tested for good overall contact. If the joint is not a good metal-to-metal fit, or if scores or leakage are evident, remove the studs from the steam cylinder and lap the steam chest in against the cylinder seat.

In making up the joint, strict cleanliness must be observed so that no particles of dirt or scale will prevent a good metal-to-metal contact of the ground faces. A thin film of copaltite should be applied. The hold-down bolts should be taken up gradually and alternately in a diagonal sequence After the pump is in operation, the hold-down bolts should be taken up again.

Do not install gaskets on the steam chest joint. Such a gasket tends to blow out around the steam passage lands, thus aggravating the cutting action of the steam.

When continued lapping of the valve chest and the steam cylinder have worn them down to the extent that they must be built up to the original dimensions, then both should be overlayed and brought back to the design dimension. When piston valve chest joints, lands, and other parts are badly damaged by wear and steam cutting, the repair procedures given in the following paragraphs are authorized by the Naval Ship Systems Command. (Refer to fig. 6-11 for identification of the areas to be repaired.)

Joint face A (fig. 6-11), between the steam chest and the cylinder, may be built up by overlaying. Both surfaces should be brought back to their design dimensions.

Main liner chest lands B may be built up by welding with a corrosion-resisting steel (25 percent chromium, 20 percent nickel) electrode.

Liners should be replaced, if possible, rather than subjected to extensive repair. However, if spare liners are not available, the individual liner may be chrome plated on the outside area C. In such cases, liners should be shrunk into place. Pressing chrome-plated liners into the chest will result in galling. Chrome plating of the inside or wearing surface of liners (area D of fig. 6-11) is not authorized; such a repair would do away with the graphitic lubrication provided by the original special alloy iron liners.

Main piston valves and the pilot valves should be replaced when worn or steam cut. Building up ring grooves E with chromium-cobalt composition is authorized, if replacement valves cannot be obtained. The original valve material has a hardness of approximately 200 Brinell; the liner, approximately 500 Brinell. Thus, wear will be taken on the pistons rather than on the more expensive liners. Therefore, overlaying of the ring grooves with a harder material than the liner should be avoided to prevent rapid wear of the liner.

The end lands of main piston valves may be found to have insufficient clearance with the liner. The clearance on diameter between end lands F and the liner should range from 0.002 to 0.0025 inch per inch of diameter. Center lands should have approximately half of this clearance.

Replacement piston rings G should be of cast iron (as originally installed) in order to obtain the required finish on the working faces.

If tail rods H are to be replaced, they should be of K-Monel to avoid corrosion and the danger of rust working loose in the valve chest. Chrome plating of the original carbon steel rods is satisfactory as a repair.

Overhauling Water End Valves

All valves in the water end of the pump must be kept tight to ensure satisfactory and economical pump operation. Valves may be faced in a lathe and then ground in on their seats by a simple device which consists of a length of rod slotted to fit a piece of metal which seats across the top of the valve.

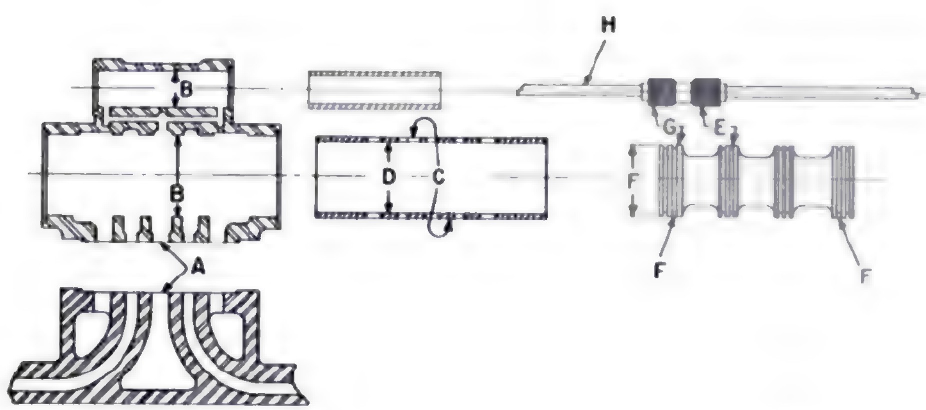

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Figure 6-11.—Repair of valve chests, liners, and piston rings.

It is sometimes desirable to take a cut off the valve seat without removing it. A simple cutter can be made with an extension for a bitstock, similar to the grinding-in device. When flat valves are fitted, the seats may be trued up by using a small surface plate and spotting-in the section on the surface plate.

Valve disks and seats should be ground in, or replaced if necessary, in accordance with Maintenance Requirement Cards and manufacturer's instructions.

After the valves have been ground in, test the valves by closing the suction valve, opening the discharge valve, starting the pump, and noting the vacuum that the pump is capable of attaining.

PUMP CONTROL AND SAFETY DEVICES

Turbines, used to drive pumps, are fitted with devices to control or limit the speed of the turbine, or to regulate the discharge pressure of the unit.

These devices are seldom found on reciprocating pumps. However, all turbine-driven rotary and centrifugal pumps have some type of governor; where discharge pressure has to be controlled, both a constant pressure governor and a speed limiting governor are installed.

SPEED LIMITING GOVERNOR

The speed of turbine-driven condensate and booster pumps is controlled by a speed limiting governor. This type of governor has no control of the pump speed until it reaches about 95 percent of maximum. Figure 6-12 shows one of the more common types used on main condensate, main feed booster, and lube oil service pumps.

The governor shaft is driven directly by an auxiliary shaft in the reduction gear and rotates at the same speed as the pump shaft. Two flyweights are pivoted to a yoke on the governor shaft and carry arms which bear on a push rod assembly. The push rod assembly is held down by a strong spring. Centrifugal force on the flyweights causes them to be thrown outward. This lifts the arms, which pivot on rollers, against the spring tension on the governor stem when the speed for which the governor is set. (Some flyweights pivot on knife edges rather than rollers.) If the turbine speed begins to exceed that for which the governor is set, increased centrifugal force acting on the rotating flyweights

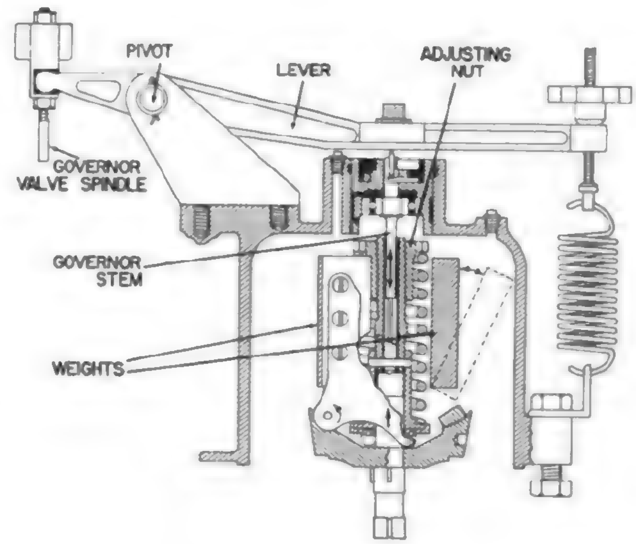

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Figure 6-12.—Speed limiting governor, main condensate pump.

will cause them to move farther out, and thereby cause the governor valve to throttle down on the steam. On the other hand, when the turbine slows down, as from an increase in load, the centrifugal force on the flyweights is reduced, and the governor push rod spring acts to pull the flyweights inward. This rotates the lever about its pivot and opens the governor valve, thus admitting more steam with a resultant speedup of the turbine until normal operating speed is reached.

Therefore, the governor acts as a constant speed governor (when the turbine is operating above 95 percent of rated speed) although it is designed only to limit the speed. The speed of the pump may vary somewhat, with a change in the load, but the variation will not be great enough to cause unsatisfactory operation of the unit.

Adjustment of the speed to which the turbine will be limited can be made by removing the cover from the governor assembly and changing the tension of the spring that works against the weights. The total travel of the governor valve, from FULLY OPEN to FULLY CLOSED, should be adjusted to 1/4 inch. This travel should be checked after each readjustment of the spring. The pump is normally operated with the throttle fully open, passing full steam pressure to the

governor valve, and thereby allowing the valve to control the speed of the unit.

Figure 6-13 shows a CENTRIFUGAL WEIGHT TYPE of SPEED LIMITING GOVERNOR for a main feed pump. Centrifugal weights are mounted on a hub which rotates with the turbine shaft. As the speed of the turbine increases, centrifugal force causes the free ends of the weights to move outward, compressing the governor spring. This action causes the sleeve to move out against one end of the governor lever. The other end of the double-poppet steam governor valve and thus cutting down the amount of steam which is admitted to the turbine. Tension on the spring at the outer end of the double-poppet valve stem tends to open the valve again, as soon as the turbine shaft has slowed down and allowed the centrifugal weights to move inward.

CONSTANT PRESSURE GOVERNOR

Many turbine-driven pumps are fitted with constant pressure pump governors. The function of a constant pressure pump governor is to maintain a constant pump discharge pressure under varying conditions of load. The governor, which is installed in the steam line to the pump, controls the pump discharge pressure by controlling the amount of steam admitted to the driving turbine.

Two types of constant pressure pump governors are used in the Navy—the Leslie governor and the Atlas governor. The two types of governors are very similar in operating principles. The discussion here is based on the Leslie governor, but most of the information applies also to the Atlas governor.

A Leslie constant pressure pump governor for a main feed pump is shown in figure 6-14. The governors used on fuel oil service pumps, lube oil service pumps, fire and flushing pumps, and various other pumps are almost identical. The chief difference between governors used for different services is in the size of the upper diaphragm. A governor used for a pump which operates with a high discharge pressure has a smaller upper diaphragm than one for a pump which operates with a low discharge pressure.

Two opposing forces are involved in the operation of a constant pressure pump governor. Fluid from the pump discharge, at discharge pressure is led through an actuating line to the

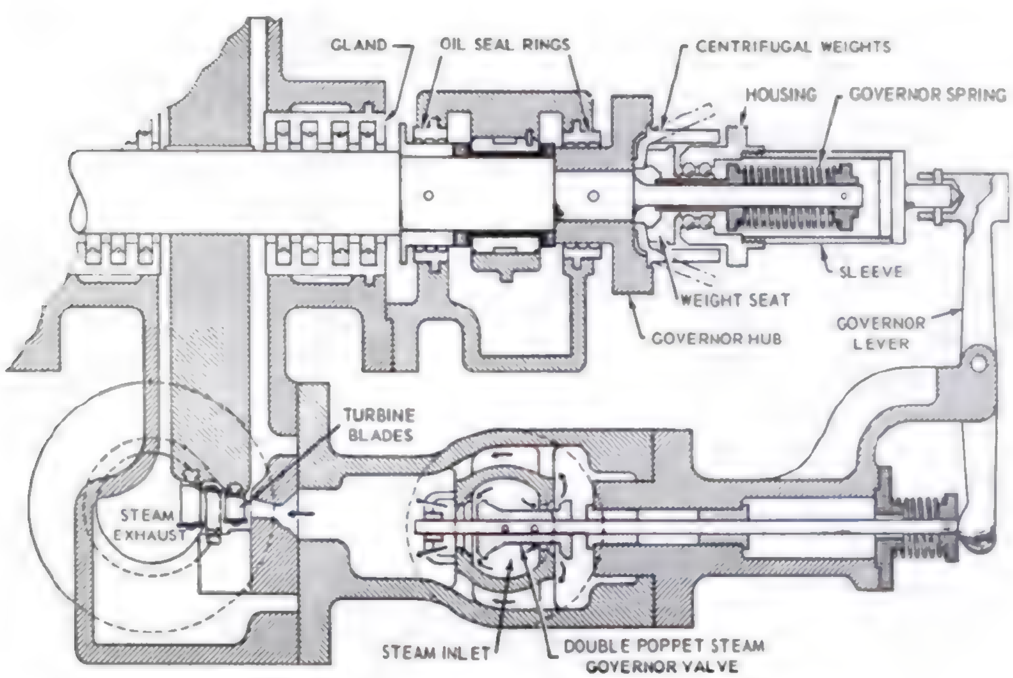

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Figure 6-13.—Speed limiting governor, main feed pump.

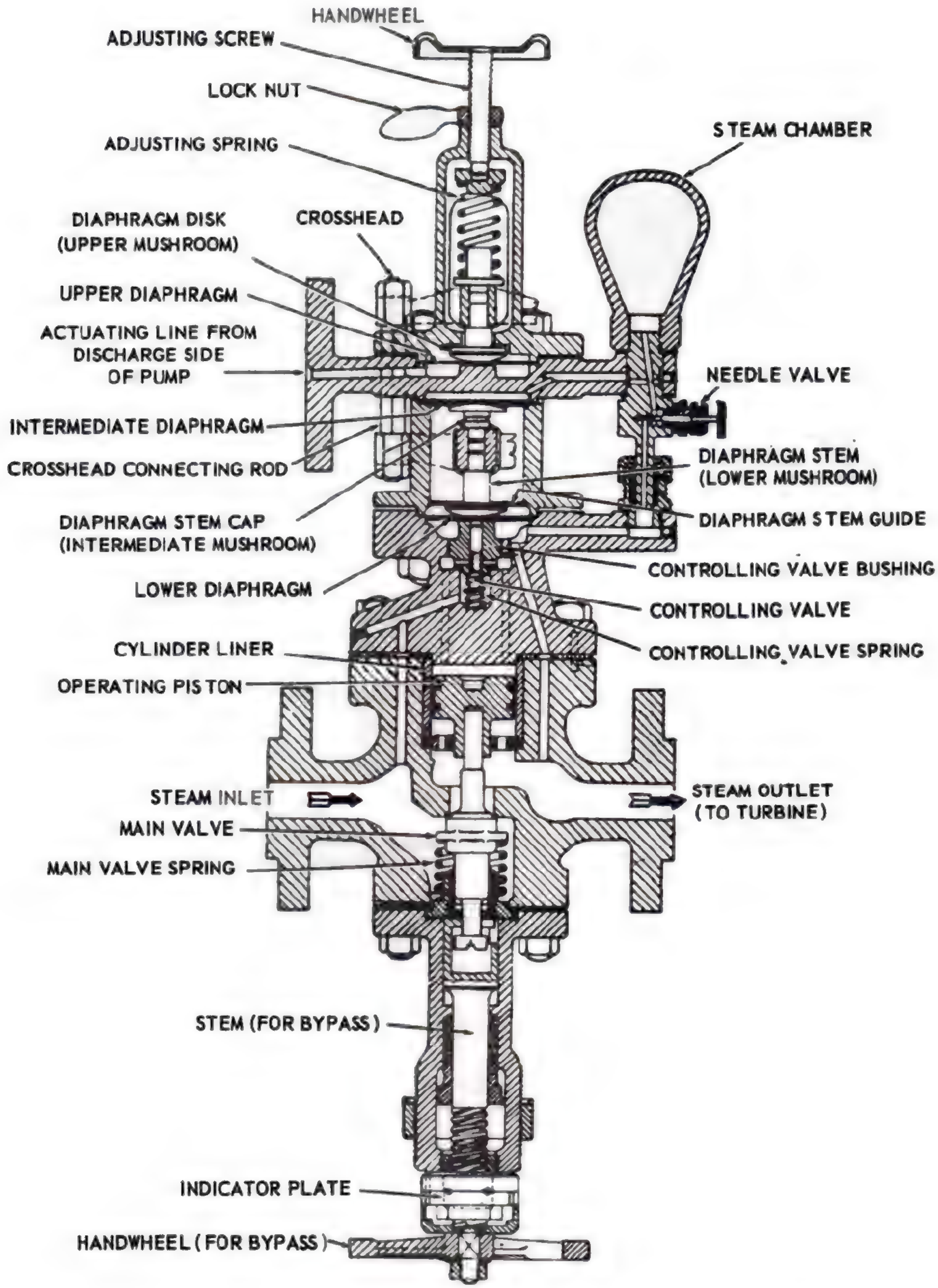

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Figure 6-14.—Constant pressure governor for main feed pump.

space below the upper diaphragm. The pump discharge pressure thus exerts an UPWARD force on the upper diaphragm. Opposing this, an adjusting spring exerts a DOWNWARD force on the upper diaphragm.

When the downward force of the adjusting spring is greater than the upward force of the pump discharge pressure, the spring forces the upper diaphragm and the upper crosshead down. A pair of connecting rods connects the upper crosshead rigidly to the lower crosshead, so the entire assembly of upper and lower crossheads moves together. When the crosshead assembly moves down, it pushes the lower mushroom and the lower diaphragm downward. The lower diaphragm is in contact with the controlling valve. When the lower diaphragm is moved down, the controlling valve is forced down and open.

The controlling valve is supplied with a small amount of steam through a port from the inlet side of the governor. When the controlling valve is open, steam passes to the top of the operating piston. The steam pressure acts on the top of the operating piston, forcing the piston down and opening the main valve. The extent to which the main valve is open controls the amount of steam admitted to the driving turbine. Increasing the opening of the main valve therefore increases the supply of steam to the turbine and so increases the speed of the turbine.

The increased speed of the turbine is reflected in an increased discharge pressure from the pump. This pressure is exerted against the under side of the upper diaphragm. When the pump discharge pressure has increased to the point where the upward force acting on the under side of the upper diaphragm is greater than the downward force exerted by the adjusting spring, the upper diaphragm is moved upward. This action allows a spring to start closing the controlling valve, which in turn allows the main valve spring to start closing the main valve against the now reduced pressure on the operating piston. When the main valve starts to close, the steam supply to the turbine is reduced, the speed of the turbine is reduced, the pump discharge pressure is reduced.

At first glance, it might seem that the controlling valve and the main valve would be constantly opening and closing and that the pump discharge pressure would be continually varying over a wide range. This does not happen, however, because the governor is designed with an arrangement which prevents excessive opening or closing of the controlling valve. An intermediate diaphragm bears against an intermediate mushroom which, in turn, bears against the top of the lower crosshead. Steam is led from the governor outlet to the bottom of the lower diaphragm and also, through a needle valve, to the top of the intermediate diaphragm. A steam chamber is provided to ensure a continuous supply of steam at the required pressure to the top of the intermediate diaphragm.

Any movement of the crosshead assembly, either up or down, is therefore opposed by the force of the steam pressure acting either on the intermediate diaphragm or on the lower diaphragm. The whole arrangement serves to prevent extreme reactions of the controlling valve in response to variations in pump discharge pressure.

Limiting the movement of the controlling valve in the manner just described reduces the amount of hunting the governor must do to find each new position. Under constant-load conditions, the controlling valve takes a position which causes the main valve to remain open by the required amount. A change in load conditions results in momentary hunting by the governor until it finds the new position required to maintain pump discharge pressure at the new load.

A pull-open device, consisting of a valve stem and a handwheel, is fitted to the bottom of the governor. Turning the handwheel to the open position draws the main valve open and allows full steam flow to the turbine. When the main valve is opened by means of this bypass arrangement the turbine must be controlled manually. Under all normal operating conditions, the bypass remains closed and the pump discharge pressure is raised or lowered, as necessary, by increasing or decreasing the tension on the adjusting spring.

An AUTOMATIC SHUTDOWN DEVICE has been developed by the Leslie Company for use on main feed pumps. The purpose of this device is to shut down the main feed pump and so protect it from damage in the event of loss of feed booster pump pressure. The shutdown device has been tested in service and has shown that it can shut down the main feed pump when the feed booster pump pressure is inadequate.

The Leslie automatic shutdown device consists of an auxiliary pilot valve and a constant pressure pump governor, arranged as shown in figure 6-15. The governor is the same as the

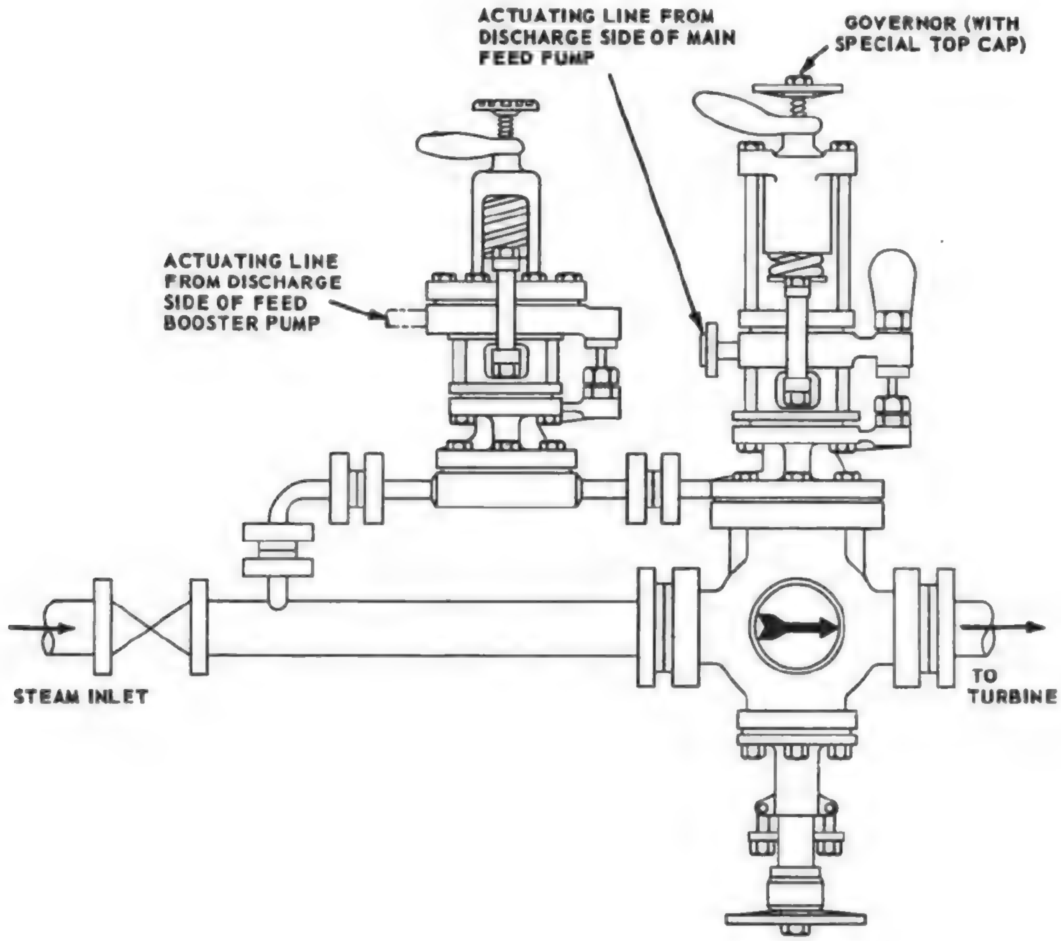

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Figure 6-15.—Automatic shutdown device for main feed pump.

Leslie governor just described except that it has a special top cap. In the regular Leslie governor, the steam for the operating piston is supplied to the controlling valve through a port in the governor valve body. In the automatic shutdown device, the steam for the operating piston is supplied to the controlling valve through the auxiliary pilot valve. The auxiliary pilot valve (fig. 6-16) is actuated by the feed booster pump discharge pressure. When the booster pump discharge pressure is inadequate, the auxiliary pilot valve will not deliver steam to the controlling valve of the governor. Thus inadequate feed booster pump pressure allows the main valve in the governor to close, shutting off the flow of steam to the main feed pump turbine.

MAINTENANCE AND REPAIR OF GOVERNORS

The maintenance and repair of governors should be accomplished in accordance with the applicable Maintenance Requirement Cards or manufacturer's instructions for the specific equipment. Information which follows is general in nature.

As far as speed limiting governors are concerned, very little wear is experienced. However, the governor must be kept clean. Dirt or other foreign matter can foul the spring, and thus require more force to move the weights, which will allow the pump to overspeed. Rust on the governor lever fulcrum pin will cause the lever to bind and not function properly. All pins in

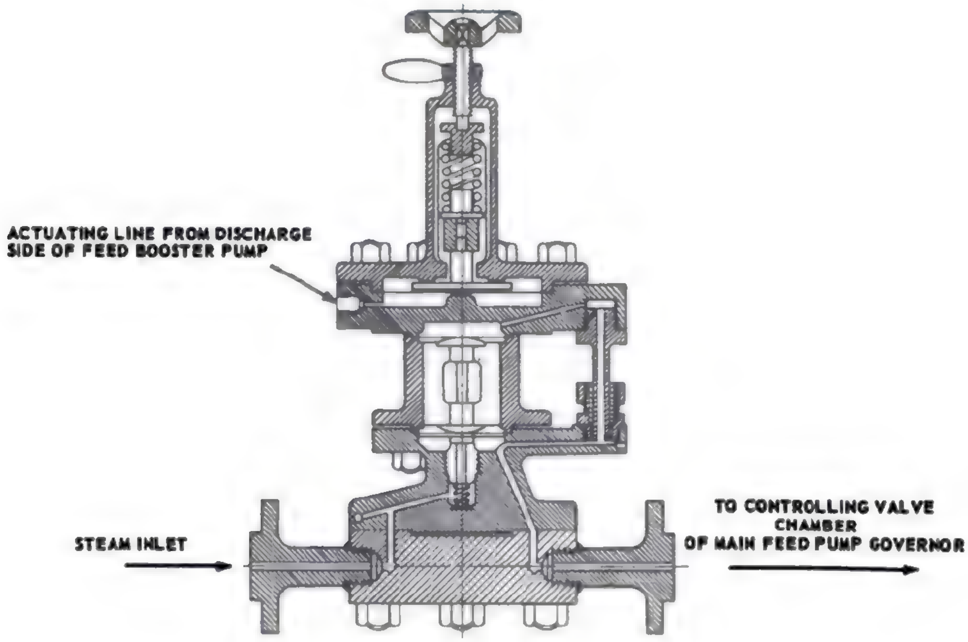

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Figure 6-16.—Auxiliary pilot valve for automatic shutdown device.

the linkage and the valve stem must be kept free of paint, rust, and dirt so that the linkage can move freely. Occasionally, a test should be made to determine whether the poppet valve (fig. 6-13) is leaking. The test may be made by pushing the valve onto its seat by hand. If the valve is leaking the turbine will continue to rotate.

When constant pressure governors are disassembled, all diaphragms should be carefully inspected. If indications of failure are found, the affected part(s) should be renewed. In performing routine overhaul maintenance of Leslie pump governors, however, it may be necessary to replace serviceable diaphragms because of distortion resulting from normal operating pressure. Unless manufacturer-furnished diaphragms are used, reference should be made to finished plans for guidance as to proper dimensions and materials.

Distortion of diaphragms, within the manufacturer's prescribed limits, is normal and has no adverse affect on the operation of governors. Unless distortion beyond the prescribed limits is found, replacement of diaphragms is not necessary.

The control or pilot valve may be a source of trouble, particularly in a Leslie pump governor. Steam, passing through the control valve, is continuously throttled, and the valve is subjected to considerable erosion (wiredrawing). The control valve and valve seat should be inspected frequently. When reassembling the control valve or installing a new one, it is very important to maintain the correct clearance between the control valve stem and the lower diaphragm. If the clearance is excessive, the lower diaphragm cannot fully open the control valve, and the pump capacity is reduced. If there is not enough clearance, the diaphragm will hold the control valve open and the pump cannot be stopped without closing the root steam valve. It is also necessary that there be no steam leakage through the control valve bushing because the leaking steam will hold the main valve open, allowing steam to flow to the turbine.

Faulty governor operation may also result from the wearing of grooves in the cylinder liner. The grooves, which limit the travel of the main valve, become worn when the piston is moved through a short travel; this reduces the capacity of the pump and causes failure of the governor. Whenever a constant pressure governor is disassembled, the liner should be

carefully checked; and if it is grooved excessively, it should be replaced in accordance with manufacturer's recommendations for the specific unit.

Control valve springs should be inspected frequently. If the spring breaks or is weak, it cannot close the control valve, which allows a full flow of steam to the turbine.

SAFETY PRECAUTIONS

The following safety precautions must be observed in connection with the operation of pumps:

1. See that all relief valves are tested at the appropriate intervals as required by the Planned Maintenance Subsystem. Be sure that relief valves function at the designated pressure.

2. Never attempt to jack over a pump by hand while the throttle valve to the turbine is open or the power is on. Never jack over a reciprocating pump when the throttle valve or the exhaust valve is open.

3. Do not attempt to operate a pump while either the speed limiting governor or the constant pressure governor is inoperable. Be sure that the speed limiting governor and the constant pressure governor are properly set.

4. Do not use any boiler feed system pump for any service other than boiler or feed water service, except in an emergency.

CHAPTER 7

PIPING, VALVES, GASKETS, AND PACKING

As an MM3 or MM2 you will be working with piping, fittings, valves, packing, gaskets, and insulation. You will be responsible for routine maintenance of this equipment in your spaces. In order for you to qualify for advancement in the Machinist's Mate rating you will have to know how to (1) make minor repairs to insulation, (2) repack high pressure valves, (3) overhaul and adjust regulating and reducing valves, (4) overhaul gate, globe, check, and other valves, (5) select the right packing and gaskets, and (6) make repairs to high and low pressure steam lines. The machinery in your space cannot operate properly unless valves and piping are kept in good working condition. This chapter covers principal difficulties encountered with valves and piping. Additional information can be found in Fireman, NAVPERS 10520-D.

PIPING AND TUBING

The Naval Ship Systems Command defines piping as an assembly or pipe or tubing, valves, fittings, and related components forming a whole or a part of a system for transferring fluids (liquids and gases).

IDENTIFICATION

In commercial usage, there is no clear distinction between pipe and tubing, since the correct designation for each tubular product is established by the manufacturer. If the manufacturer calls a product pipe, it is pipe; if he calls it tubing, it is tubing.

In the Navy however, a distinction is made between pipe and tubing. This distinction is based on the way the tubular product is identified as to size.

There are three important dimensions of any tubular product: outside diameter (OD), inside diameter (ID), and wall thickness. A tubular product is called TUBING if its size is identified by actual measured outside diameter (OD) and by actual measured wall thickness. A tubular product is called PIPE if its size is identified by a nominal dimension called IRON PIPE SIZE (IPS) and by reference to a wall thickness schedule designation.

The size identification of tubing is simple enough, since it consists of actual measured dimensions; but the terms used for identifying pipe sizes may require some explanation. A NOMINAL dimension such as iron pipe size (IPS) is close to—but not necessarily identical with—an actual measured dimension. For example, a pipe with a nominal pipe size of 3 inches has an actual measured outside diameter of 3.50 inches. A pipe with a nominal pipe size of 2 inches has an actual measured outside diameter of 2.375 inches. In the larger sizes (about 12 inches) the nominal pipe size and the actual measured outside diameter are the same. For example, a pipe with a nominal pipe size of 14 inches has an actual measured outside diameter of 14 inches. Nominal dimensions are used in order to simplify the standardization of pipe fittings and pipe taps and threading dies.

The wall thickness of pipe is identified by reference to wall thickness schedules established by the American Standards Association. For example, a reference to schedule 40 for a steel pipe with a nominal pipe size of 3 inches indicates that the wall thickness of the pipe is 0.216 inch. A reference to schedule 80 for a steel pipe of the same nominal pipe size (3 inches) indicates that the wall thickness of the pipe is 0.300 inch.

A schedule designation does NOT identify any one particular wall thickness unless the nominal pipe size is also specified. For example, we have seen that a schedule 40 steel pipe of nominal pipe size 3 inches has an actual wall thickness of 0.216 inch. But if we look up schedule 40 for a steel pipe of nominal pipe 4 inches, we will find that the wall thickness is 0.237 inch.

These examples are used merely to illustrate the meaning of wall thickness schedule designations. Many other values can be found in pipe tables given in engineering handbooks.

You have probably seen pipe identified as STANDARD (Std), EXTRA STRONG (XS), and DOUBLE EXTRA STRONG (XXS). These designations, which are still used to some extent, also refer to wall thicknesses. However, pipe is manufactured in a number of different wall thicknesses, and some pipe does not fit into the standard, extra strong, and double extra strong classifications. The wall thickness schedules are being used increasingly to identify the wall thickness of pipe because they provide for the identification of more wall thicknesses than can be identified under the strong, extra strong, and double extra strong classifications.

The standard ways of identifying size and wall thickness of pipe and tubing have been briefly described here. It should be noted, however, that you will sometimes see pipe and tubing identified in other ways. For example, you may see some tubing identified by ID rather than by OD. And you may see some pipe identified by nominal pipe size, by OD, by ID, and by actual measured wall thickness.

PIPING MATERIALS

A great many different kinds of pipe and tubing are used in shipboard piping systems. Some shipboard applications of pipe and tubing that may be of particular interest to MMs are mentioned here.

SEAMLESS CHROMIUM-MOLYBDENUM ALLOY STEEL PIPE is used for some high pressure, high temperature steam systems. The upper limit for the piping is 1500 psig and 1050° F.

SEAMLESS CARBON STEEL TUBING is used in oil, steam, and feed water lines operating at 775° F and below. Different types of this tubing are available; the type used in any particular system depends on the working pressure of the system.

SEAMLESS CARBON-MOLYBDENUM ALLOY STEEL TUBING is used for feed water discharge piping, boiler pressure superheated steam lines, and boiler pressure saturated steam lines. Several types of this tubing are available; the type used in any particular case depends upon the boiler operating pressure and the superheater outlet temperature. The upper pressure and temperature limits for any class of this tubing are 1500 psi and 875° F.

SEAMLESS CHROMIUM-MOLYBDENUM ALLOY STEEL TUBING is used for high pressure, high temperature steam service on modern ships. This type of alloy steel tubing is available with different percentage of chromium and molybdenum with upper limits of 1500 psig and 1050° F.

WELDED CARBON STEEL TUBING is used in some water, steam, and oil lines where the temperature does not exceed 450° F. There are several types of this tubing; each type is specified for certain services and certain service conditions.

NONFERROUS PIPE and NONFERROUS TUBING are used for many shipboard piping systems and for most shipboard heat exchangers. Nonferrous materials are used chiefly where their special properties of corrosion resistance and high heat conductivity are required. Various types of SEAMLESS COPPER TUBING are used for refrigeration installations, plumbing and heating systems, lubrication systems, and other shipboard systems. COPPER-NICKEL ALLOY TUBING is available in composition 70-30 (70 percent copper and 30 percent nickel) and in composition 90-10 (90 percent copper and 10 percent nickel). The 70-30 composition is generally used in submarine piping systems and heat exchangers. The 90-10 composition is widely used in surface ships.

Many other kinds of pipe and tubing besides the kinds mentioned here are used in shipboard piping systems. It is important to remember that design considerations control the selection of any particular pipe or tubing for any particular system. Although many kinds of pipe and tubing look almost exactly alike from the outside, they may respond very differently to pressures, temperatures, and other service conditions. Therefore, each kind of pipe and tubing can be used ONLY for specified applications.

PIPING SYSTEMS

Aboard ship the various units of machinery and equipment are connected by miles of piping. Each piping system consists of sections of piping or tubing, fittings for joining the sections, and valves for controlling the flow of fluid. Most piping systems also include other fittings and accessories such as vents, drains, traps, strainers, relief valves, and various gages and

instruments. In this chapter we will briefly discuss some of the engineering piping systems with which Machinist's Mates are concerned.

Main Steam System

The main steam system is the shortest and simplest of all the major engineering piping systems aboard ship. This statement is true regardless of the steam pressures involved. With the recent advent of the 1200-psi main steam system, there is a tendency to regard high pressure main steam systems as being mysteriously more complicated than the lower pressure systems. In reality, a 1200-psi main steam system serves the same basic purpose as a lower pressure system, and differs only in minor details. The major differences between high pressure main steam systems and lower pressure systems is in the materials used for piping and fittings; in general, the metals for 1200-psi systems must be designed to withstand operating temperatures approximately 100° to 200° F higher than the operating temperatures of the lower pressure systems.

On most ships, any piping which carries superheated steam is considered as part of the main steam system. On many ships, the main steam system includes only the piping that carries superheated steam from the boilers to the propulsion turbines, the turbogenerators, and the soot blowers. On some recent ships, both 600-psi and 1200-psi, the main steam system supplies superheated steam to several other units as well. For example, some carriers use superheated steam to supply steam catapult systems; also, some carriers and other ships use superheated steam to operate forced draft blowers, main feed pumps, main circulating pumps, and other auxiliaries. The soot blowers are NOT supplied from the main steam system on some ships that have 1200-psi main steam systems; instead, steam for the soot blowers is taken from a 1200-psi auxiliary steam system. On ships having two main propulsion plants, the forward and after systems can be cross-connected by piping and valves between the forward engineroom and the after fireroom. By means of this piping, any boiler may supply steam to any main engine or any turbogenerator. Thus the propulsion plants may be operated independently (split plant) or by the cross connected plant. On ships having four main propulsion plants, the systems are arranged for forward group and after group operation. The two forward plants may be operated cross connected, or all four plants may be operated independently (split plant).

Auxiliary Steam Systems

Auxiliary steam systems supply saturated steam for the operation of many systems and units of machinery, both inside and outside the engineering spaces. Constant and intermittent service steam systems, steam smothering systems, air compressors, whistles, sirens, air ejectors, and a wide variety of pumps are typical of the systems and machinery that use auxiliary steam. Most ships have a 600 psi auxiliary steam system and a 150 psi system. The 600 psi system serves some machinery directly and also supplies the 150 psi system through reducing valves. The 150 psi system serves some units directly and also provides steam, through reducing valves, for units and systems which require steam at pressures lower than 150 psi. Auxiliary steam systems are normally arranged in loop form, with cross connections at required intervals to provide for split plant or cross connected operation.

Ships that have a 1200-psi main steam system have a 1200-psi auxiliary steam system, a 600-psi auxiliary steam system, a 150-psi auxiliary steam system, and several constant and intermittent steam service systems.

Auxiliary Exhaust System

The auxiliary exhaust system receives exhaust steam from machinery which does not exhaust directly to a condenser. Auxiliary exhaust is used in various units such as deaerating feed tanks, distilling plants, and (on most ships) gland sealing systems. The pressure is maintained at 15 psig. If the pressure becomes too high, automatic unloading valves (dumping valves) allow the excess exhaust to go to the main or auxiliary condenser. If the pressure drops too low, makeup steam is supplied from the 150 psi steam system through pressure controlled reducing valves or by manually operated valves.

Condensate and Feed Systems

The condensate and feed systems include all the piping that carries water from the condenser to the boilers and from the feed tanks to the boilers or the condenser. The condensate system includes the main and auxiliary condensers,

condensate pumps and piping. The boiler feed system includes the feed booster pumps, the feed pumps, and the piping required to carry water from the deaerating feed tank. Since the condensate and feed systems form one continuous system, the terms feed system and feed water system are quite commonly used to include both the condensate and the boiler feed water systems.

Steam and Fresh Water Drain Systems

Most of the feed water in a shipboard steam plant is recovered so it can be used over and over again for the generation of steam. Steam is condensed in the main and auxiliary condensers and the condensate is returned to the feed system. The auxiliary exhaust is used in the deaerating feed tank and so becomes part of the feed system. But steam is used throughout the ship in equipment and piping which does not exhaust to a condenser or to the auxiliary exhaust system. Therefore, steam and fresh water drain systems are provided so that water can be recovered and put back into the feed system. The systems of piping which carry the water to the feed system, and also the water carried in the systems, are known as drains. On ships built to Navy specifications, there are four steam and fresh water drain systems which recover water from machinery end piping: (1) the high pressure steam drain system, (2) the service steam drain system, (3) the oil heating drain system, and (4) the fresh water or low pressure drain collecting system. A fifth system is provided for collecting contaminated drains which cannot be returned to the feed system. These five drain systems are described briefly in the following sections.

High Pressure Drain System

High pressure drains generally include drains from superheater headers, throttle valves, main and auxiliary steam lines and other steam equipment and systems which operate at pressures of 150 psi or above. On most ships, the high pressure drains are led directly to the deaerating feed tank, where the remaining heat is used to heat the feed water. On some new ships, the high pressure drains go into the auxiliary exhaust system, just before the exhaust enters the deaerating feed tank. In either arrangement the high pressure drains end up in the same place—the deaerating feed tank.

Service Steam Drain System

The service steam drain system collects drains from low pressure (below 150 psi) steam piping systems and steam equipment outside of machinery spaces. Space heaters and the equipment used in the laundry, tailor shop, and galley are typical sources of drains for the service steam drain system. On some ships these drains are discharged into the fresh water drain collecting system. On some large ships, these drains discharge to special service steam drain collecting tanks located in the machinery spaces. The contents of the service steam drain collecting tanks are discharged to the condensate system. Each tank has gravity drain connections to the bilges.

Oil Heating Drain System

The oil heating drain system collects drains from the steam side of the fuel oil heaters, lube oil heaters, and other steam equipment used to heat oil. Since leakage in the heating equipment could cause oil contamination of the drains and eventually oil contamination of the boilers, these drains are collected separately and inspected before they are discharged to the feed system. The oil heating drains are collected in drain mains and then discharged to inspection tanks. The inspection tanks have a glass strip along the side through which the water can be inspected for the presence of oil. Normally, the inspection tanks discharge to the deaerating feed tanks; however, they have connections to the fresh water drain collecting tanks and to the bilges.

Fresh Water Drain Collecting System

The fresh water drain collecting system (often called the low pressure drain collecting system) collects drains from various piping systems, machinery, and equipment which operate at steam pressures less than 150 psi. The fresh water drain collecting system collects gravity drains (open funnel), turbine gland seal drains, auxiliary exhaust drains, air ejector after condenser drains, and other low pressure drains that result from condensation of steam during warming up or the operation of machinery and piping. Fresh water drains are collected in the fresh water drain collecting tank and enter the feed system in two ways: (1) they may be

drawn into the main auxiliary condenser by vacuum drag, or (2) in some installations they may be pumped into the condensate line just ahead of the deaerating feed tank.

Contaminated Drain System

A contaminated drain system is installed in each main and auxiliary machinery space. The contaminated drain system collects oil and water from machinery and piping which normally has some leakage and from any other services which may at times be contaminated. These drains are collected in a bilge sump tank and are pumped overboard by the bilge drainage system.

PIPE FITTINGS

Piping sections of the proper size and material are connected by various standard fittings, including several types of threaded, bolted, welded, silver-brazed, and expansion joints.

Threaded Joints

The threaded joints are the simplest type of pipe fittings. Threaded fittings are not widely used aboard modern ships except in low pressure water piping systems. The union fittings are provided in piping systems to allow the piping to be taken down for repairs and alterations. Unions are available in many different materials and designs to withstand a wide range of pressures and temperatures. Figure 7-1 shows some commonly used types of unions. The union is used a great deal for joining piping up to 2 inches in size. The pipe ends connected to the union are threaded, silver-brazed, or welded into the tail pieces; then the two ends are joined by setting up on the union ring. The male and female connecting ends of the tail pieces are carefully ground to make a tight metal-to-metal fit with each other. Welding or silver-brazing the ends to the tail pieces prevents contact of the carried fluid or gas with the union threading.

Bolted Flange Joints

Bolted flange joints (fig. 7-2) are suitable for all pressures now in use. The FLANGES are attached to the piping by welding, brazing, screw threads (for some low pressure piping), or rolling and bending into recesses. Those illustrated in figure 7-2 are the most common types of flange joints used. The same types of standard fitting shapes (tee, cross, elbow, etc.)

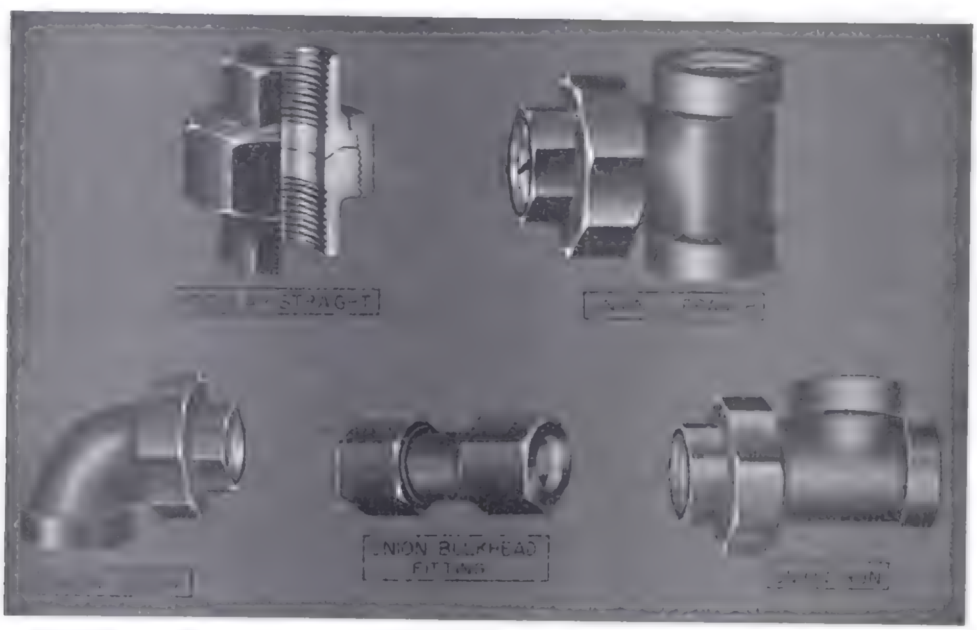

Figure 7-1.—Unions.

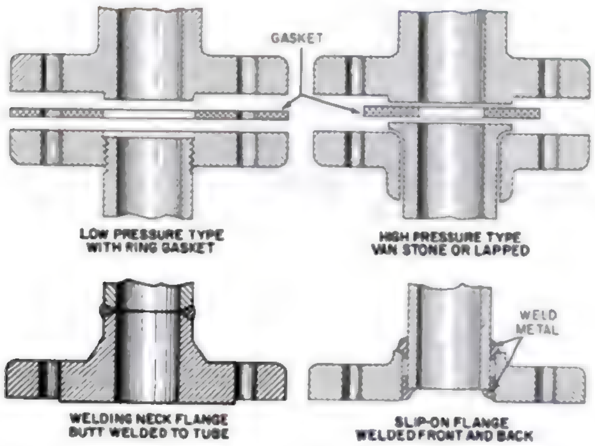

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Figure 7-2.—Four types of bolted flange piping joints.

are manufactured for flange joints, such as the threaded fittings (illustrated in Fireman, NAVPERS 10524-D). The Van Stone type and the welding neck-type flange joints are used extensively where piping is subjected to high pressures and heavy expansion strains.

Welded Joints

The majority of joints found in subassemblies of piping systems are welded joints, especially in high pressure piping. The welding is done according to standard specifications which define the materials and techniques. There are three general classes of welded joints—butt-weld, fillet-weld, and socket-weld (fig. 7-3).

Silver-Brazed Joints

Silver-brazed joints (fig. 7-4) are commonly used for joining nonferrous piping in the pressure and temperature range where its use is practicable. These practical factors limit this joint's use to steam lines not exceeding 425° F; for cold lines, these fittings may be used for pressures up to 3000 psi. The alloy is melted by heating the joint with an oxyacetylene torch. This causes the molten metal to fill the few thousandths of an inch annular space between the pipe and the fitting.

Expansion Joints

Expansion joints of various types are installed at suitable intervals in long steam lines, because of the expansion and contraction of metal subjected to a wide range of temperature. The types include the slip joint, expansion bends, corrugated joints, and bellows joints.

The SLIP JOINT (fig. 7-5) is used for low pressures, such as auxiliary exhaust piping. A slip joint consists of a stuffing box, packing gland, male sliding tube, female receptacle tube, and stop bolts (to prevent separation of male and female sections of the joint).

EXPANSION BENDS are employed for high pressure and high temperature steam piping in preference to the slip joint. Expansion bends are merely loops of piping of proper length and configuration to take up the changes in pipe length caused by temperature changes. The expansion bends take many shapes—most common are the U-bend, Z-bend and L-bend.

The CORRUGATED and BELLOWS TYPES of the expansion joints (fig. 7-6) are used for both medium and high pressures and temperatures. The principle of these joints is obvious: the expansion-contraction movement is absorbed by the changing curvature of the corrugations or bellows (as with an accordion). The internal sleeves, free to slide axially in these joints, serve to prevent excessive turbulence and erosion of the expansion parts. Figure 7-7 illustrates a corrugated BULKHEAD EXPANSION JOINT, which is designed to provide for both radial and axial movement of piping, with respect to the bulkhead.

Pipeline Strainers

Strainers are fitted in all piping lines to prevent the passage of grit, scale, dirt, and other foreign matter. Such matter could obstruct pump or throttle valves, or damage machinery parts. Various types of strainers are used, depending upon the service intended.

The BILGE SUCTION STRAINER is located in the bilge pump suction line between suction manifold and pump. Any debris which enters the piping will collect in the strainer basket. The basket is removed for cleaning by loosening the strong-back screws, removing the cover, and lifting out the basket by its handle. These strainers should be cleaned at least every 24 hours while in port, and every 4 hours while underway. The basket-type strainers, provided in most lube oil systems, are fitted with magnets

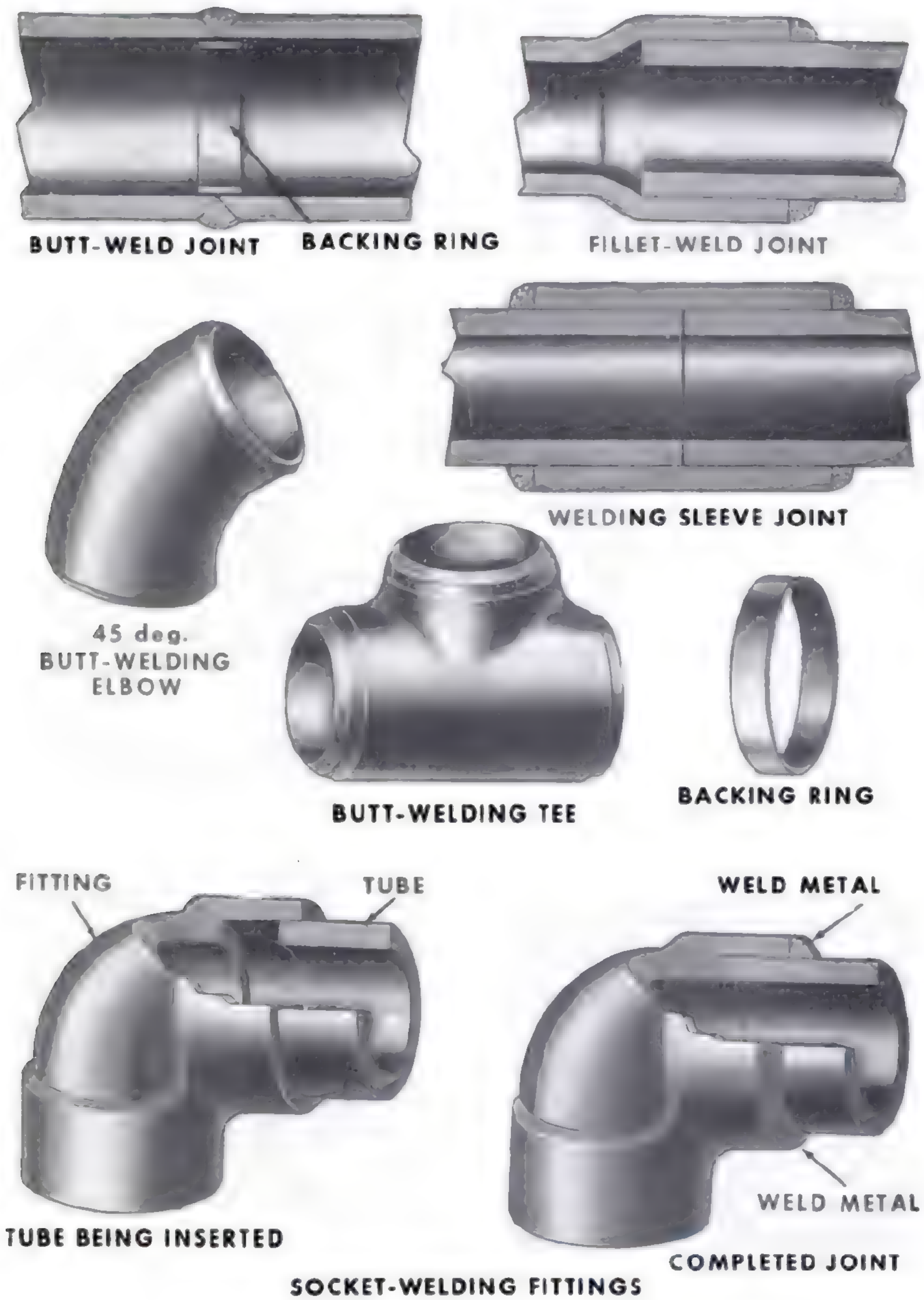

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Figure 7-3.—Various types of welded joints.

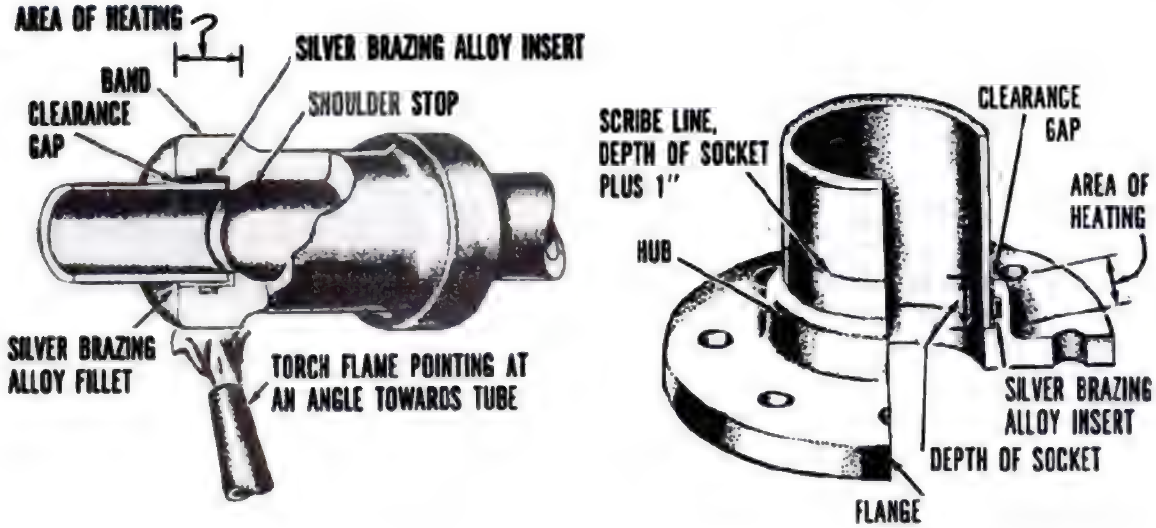

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Figure 7-4.—Silver-brazed joints.

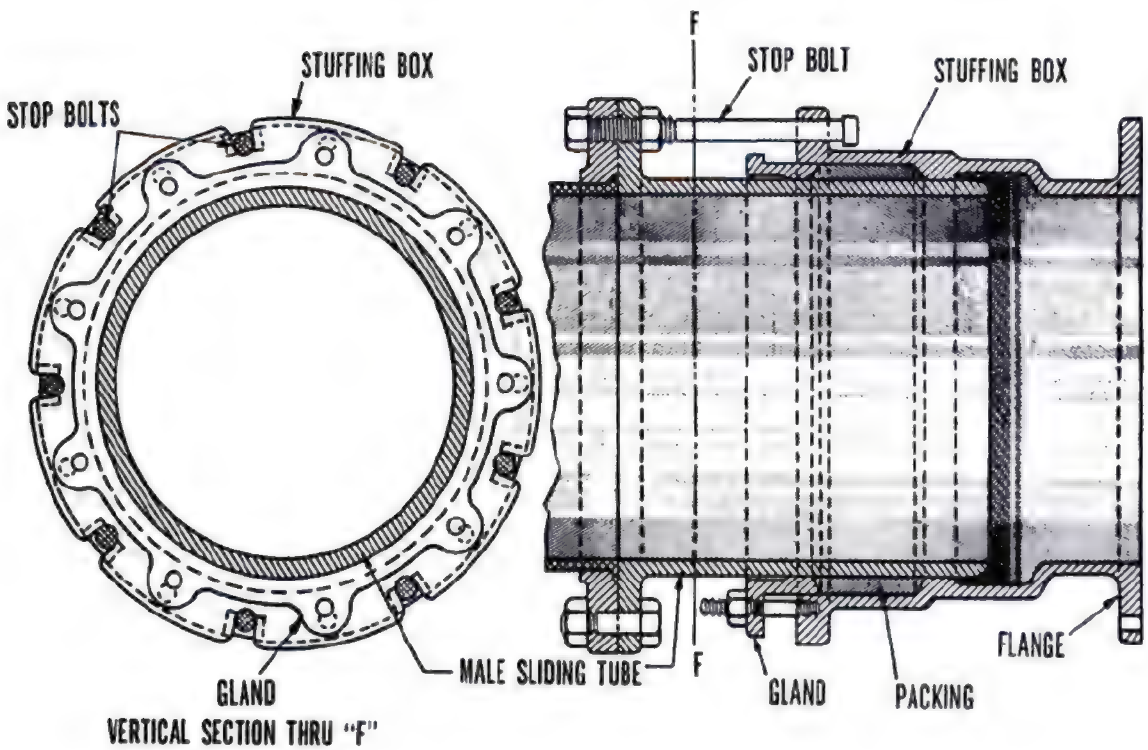

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Figure 7-5.—Slip type expansion joints.

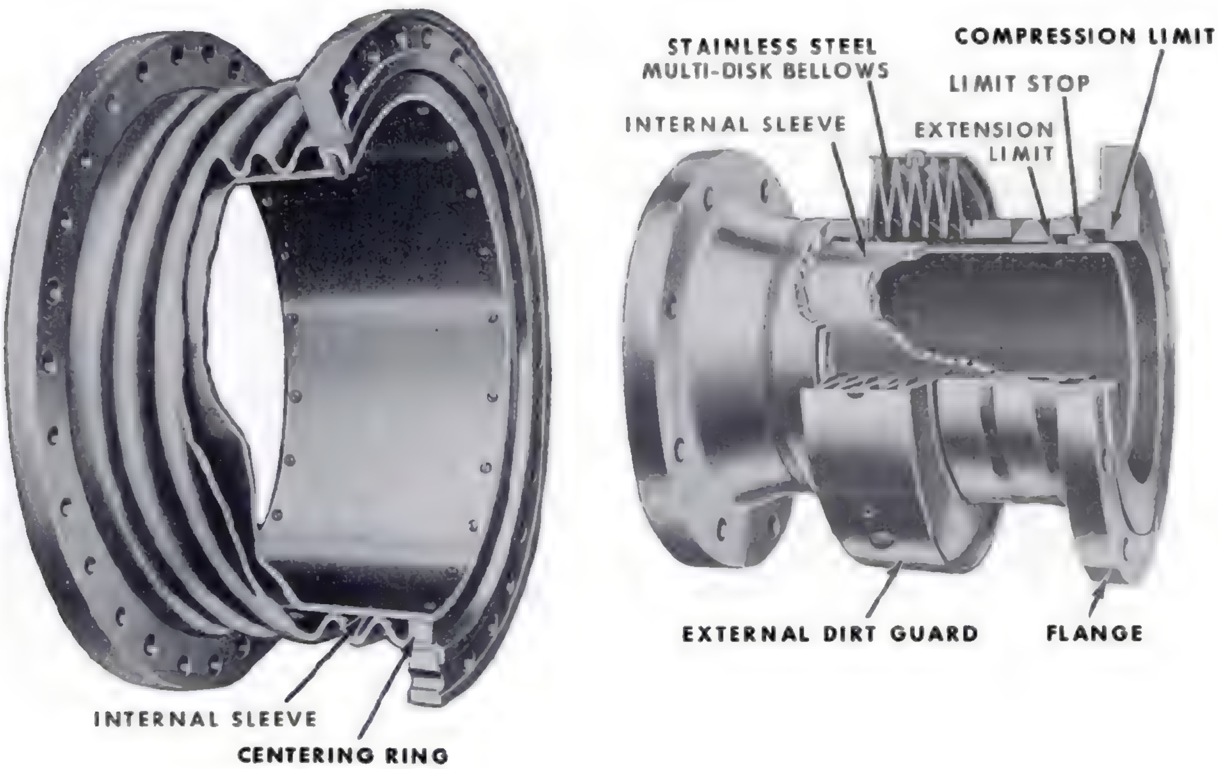

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Figure 7-6.—Corrugated type and bellows type expansion joints.

which catch any small metallic particles that may be in the lube oil. When cleaning these strainers, metallic particles that adhere to the magnets should be removed.

DUPLEX OIL STRAINERS are generally used in fuel or lube oil lines, where it is important that an uninterrupted flow be maintained. The flow may be diverted from one strainer basket to the other, while one is being cleaned. The shutoff device works on the principle of a four-way cock.

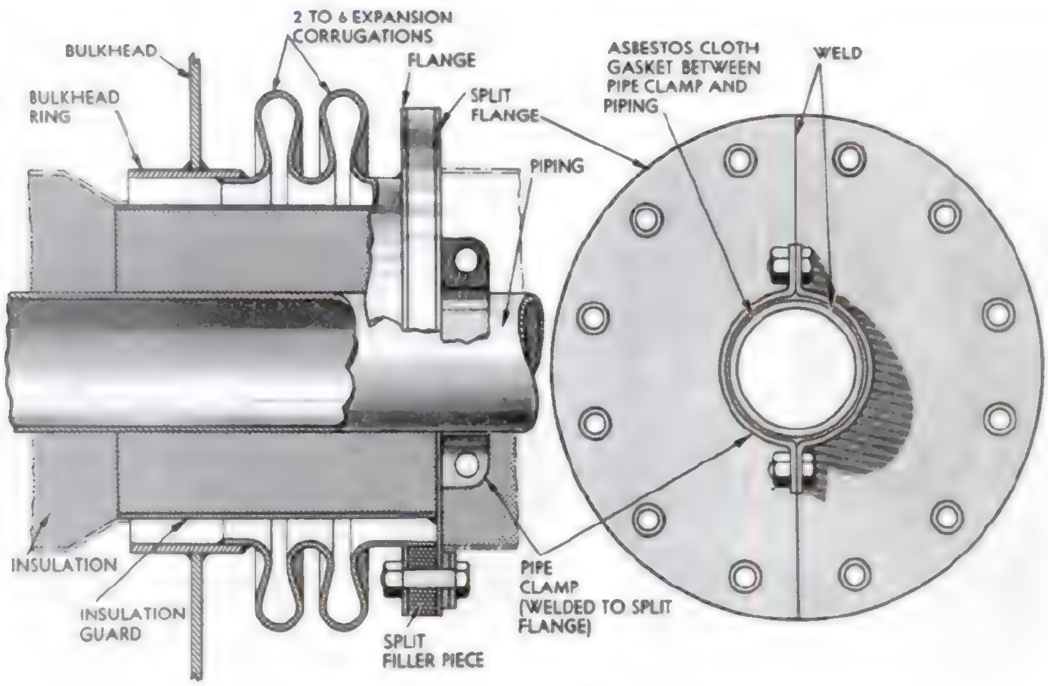
Before removing a basket for cleaning a duplex strainer, open the drain at the bottom of the casing and drain off all entrapped oil. Back off on the binding screw or head nuts a few turns; if there is no oil seepage around the cover, it is safe to remove the cover. Remove the basket, replace the cover, and close the drain. After the basket has been cleaned and inspected, repeat the above procedure and test for leaks.

CAUTION: Never start to clean a strainer basket without first shifting to the other basket. After replacing the basket in a duplex strainer, it should be refilled with oil in order not to have an interrupted flow of oil when shifting strainers again. Serious fires have occurred when inexperienced personnel have tried to remove a strainer basket while it was still in service. A lot of oil can spray out awfully fast if you open the wrong side of a duplex oil strainer.

A MANIFOLD STEAM STRAINER is desirable where space is limited, since it eliminates the use of separate strainers and their fittings. The cover is located so that the strainer basket can be easily removed for cleaning.

PIPING CARE AND MAINTENANCE

REASONABLE CARE must be given the various piping assemblies, as well as the machinery connected by the piping. All joints, valves, and cocks in the lines must be examined frequently, and kept tight. The piping on any



47.58X
Figure 7-7.—Corrugated bulkhead expansion joint, showing details of installation.

ship should not be subjected to strains by being used for handholds or footholds, by having chain falls secured to them, or by being used for supporting weights.

Where piping passes through decks or bulkhead, and a possibility exists for movement of one with respect to the other, stuffing boxes of flexible bulkhead connections are provided—if expansion bends or other offsets are not provided in the piping—to take up the movement. The external surfaces of uncovered and ungalvanized steel or iron piping should be kept properly painted and free of moisture. Copper and brass piping is seldom painted.

Continual LEAKAGE AT A JOINT where a branch line joins another line is usually due to improper allowance for expansion in one or the other line, or to excessive vibration. A slight alteration in the anchorages, connections, hangers, or leads of the piping, to allow the required expansion and prevent strain, or the fitting of supports which will prevent vibration, will often correct such leaks. Leaky joints may also be due to poor alignment of the piping, or to movement of decks or bulkheads. Realignments should be made so that flanges or screw threads meet properly without forcing. Sometimes the flange joints may have to be refaced, or distance pieces fitted. Small leaks in gaskets should be taken up immediately, before a dangerous blowout results from progressive growth of the leak.

PIPE THREAD LEAKS should be promptly corrected. Leaky screwed joints which cannot be tightened with a reasonable amount of pullup should be taken apart, cleaned, examined for bad thread conditions, recoated with the appropriate compound, and carefully reassembled, to avoid any other thread damage. Poorly cut threads are a constant source of trouble with threaded pipe joints. The proper use and care of pipe cutters will prevent such pipe troubles as shaved thread, wavy thread, and poor shoulders.

PERMANENT OR SEMIPERMANENT REPAIRS of leaky piping sections are generally made by or with the aid of the Hull Maintenance Technicians. Permanent repairs of copper or brass piping may be made by brazing. Small holes may be plugged with a rivet or a screw plug. Semipermanent repairs of leaky piping sections may be made by serving the piping with tightly drawn wire, soldered or brazed as it is applied. Several layers of wire securely bonded give a strong, tight repair.

The life of SALT WATER PIPING may be lengthened by operating the systems with minimum practical water velocities; by eliminating grounds from electrical systems, especially d-c circuits; by eliminating air from the salt water systems; by promptly correcting any leaks; by insulating with sheet rubber the hangers which support piping other than that made of wrought iron or steel; and by eliminating wire-drawing, by fully opening valves where throttling is unnecessary.

PIPING SAFETY PRECAUTIONS

The following safety precautions should be taken whenever you work on steam or hot water lines.

1. To prevent water hammer drain steam piping of water before admitting steam.
2. Before opening large steam valves, open bypasses to warm lines and equalize pressures; if bypasses are lacking, "crack" the valves.
3. Open trap bypasses when admitting steam to piping.
4. When breaking a flange joint, particularly in steam and hot water lines or in those salt water lines which have a possibility of direct connection with the sea, special precautions should be taken to ensure that:

    (a) There is no pressure on the line.

    (b) The valves cutting pressure off the part of the line undergoing repair are secured in such a manner that they cannot be accidentally opened.

    (c) The line is completely drained.

    (d) Two of the flange-securing nuts (diametrically opposite if possible) remain in place while the others are being removed. The two remaining nuts should then be slacked sufficiently to allow breaking the joint. If the line is clear, all the nuts may be removed. This precaution is necessary to prevent accidents such as scalding personnel or flooding compartments.

5. After remaking a steam joint, tighten up on the nuts according to prescribed methods.
6. Do not use piping for handholds or footholds.
7. Secure copper and brass piping free from contact with bilges. The brackets should be lined with electrical insulating material to prevent direct contact between piping and any of the ship's structure.

VALVES

Valves are usually made of bronze, brass, cast or malleable iron, or steel. Steel valves are either cast or forged, and are made of either plain steel or alloy steel. Alloy steel valves are used in high pressure, high temperature systems; the disks and seats of these valves are usually surfaced with a chromium-cobalt alloy known as STELLITE. Stellite is extremely hard.

Brass and bronze valves are never used where temperatures exceed 550° F. Steel valves are used for all services above 550° F, and in lower temperature systems where internal or external conditions of high pressure, vibration, or shock would be too severe for valves made of brass or iron. Bronze valves are used almost exclusively in systems carrying salt water. The seats and disks of these valves are usually made of Monel, a metal which has excellent corrosion and erosion resisting qualities.

PRESSURE CONTROL VALVES

In Fireman, NAVPERS 10520-D, information was given on the common stop valves, (globe, gate, plug, piston, needle, and throttle valves) and check valves. Therefore, this section will deal with pressure control valves.

There are many types of automatic pressure control valves—some of them merely providing an escape for pressures exceeding the normal pressure; some providing only for the reduction of pressure; and some providing for the regulation of pressure. The valves discussed here are known as relief valves, reducing valves, unloading valves, thermostatically controlled valves, sentinel valves, and diaphragm control valves with air operated pilots. The principle of operation of the constant pressure pump governor valves is discussed in this training manual in chapter 6, Pump Operation and Maintenance.

Relief Valves

RELIEF VALVES (fig. 7-8) are automatic valves used on steam, water, and oil lines, and on various units of machinery. Relief valves prevent the building up of an excessive pressure due to sudden closing of outlet valves, failure of regulating or reducing valves, or other causes.

Generally speaking, a relief valve consists of a valve body containing a valve disk, the stem

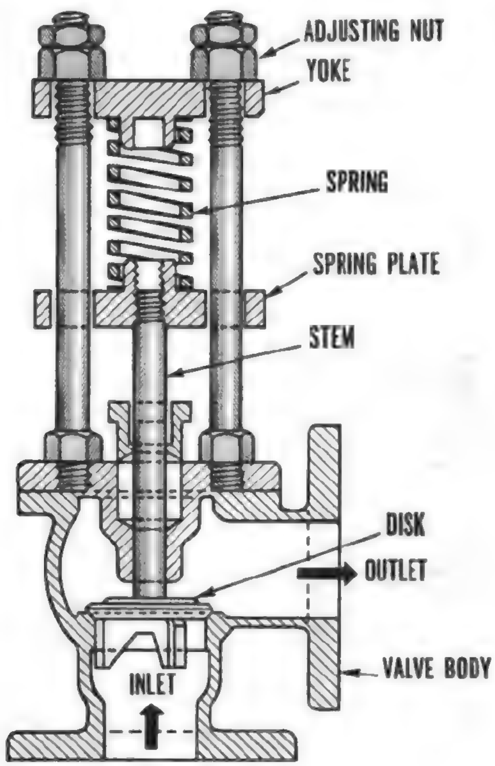


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Figure 7-8.—Relief valve.

of which extends into a spring plate. The compression of the heavy spring (shown in fig. 7-8) tends to hold the valve down on its seat. The desired setting is attained by manipulation of the adjusting nuts. When the total pressure in the valve inlet exceeds the resistance of the spring on top of the valve, the valve is forced open and the pressure relieved until it falls below that for which the valve is set.

Sentinel Valves

Small spring-loaded sentinel valves are sometimes attached to the inlet chamber of relief valves, to give warning of dangerous pressures. Sentinel valves operate on the same principle as relief valves.

Pressure Reducing Valves

Reducing valves are automatic valves which are used to provide a steady pressure lower than the supply pressure. Reducing valves are used on gland seal lines, galley steam lines, heating steam lines, and on many other reduced pressure lines. A reducing valve can be set for any desired discharge pressure, within the limits of the design of the valve. After the valve is set, the reduced pressure will be maintained regardless of changes in the supply pressure (as long as the supply pressure is at least as high as the desired delivery pressure) and regardless of the amount of reduced pressure steam that is used. Two general types of reducing valves have been in common use: the spring-loaded reducing valve, and the pnuematic pressure controlled (or gas-loaded) reducing valve. On recently built combat ships, a third type is being used, the diaphragm control valve.

SPRING-LOADED REDUCING VALVES.—The principal parts of a spring-loaded reducing valve (fig. 7-9) are: (1) the main valve, an upward-seating valve which has a piston on top of its stem; (2) an upward-seating auxiliary (or controlling) valve; (3) a controlling diaphragm; and (4) an adjusting spring.

High pressure steam (or other fluid) enters the valve on the inlet side and acts against the main valve disk, tending to close the main valve. However, high pressure steam is also led through ports to the auxiliary valve, which controls the admission of high pressure steam to the top of the main valve piston. The piston has a larger surface area than the main valve disk; therefore, high pressure steam acting on the top of the main valve piston will tend to open the main valve, and so allow steam at reduced pressure to flow out the discharge side.

But what makes the auxiliary valve open to allow high pressure steam to get to the top of the main valve piston? The controlling diaphragm transmits a pressure downward upon the auxiliary valve stem, and this tends to open the valve. However, reduced pressure steam is led back to the chamber beneath the diaphragm; and the steam exerts a pressure upward on the diaphragm, which tends to close the auxiliary valve. The position of the auxiliary valve, therefore, is determined by the position of the controlling diaphragm.

The position of the diaphragm at any given moment is determined by the relative strength of two opposing forces: (1) the downward force exerted by the adjusting spring; and (2) the upward force which is exerted on the underside of the diaphragm by the reduced pressure steam. These two forces are continually seeking to reach a state of balance; and, because of this, the

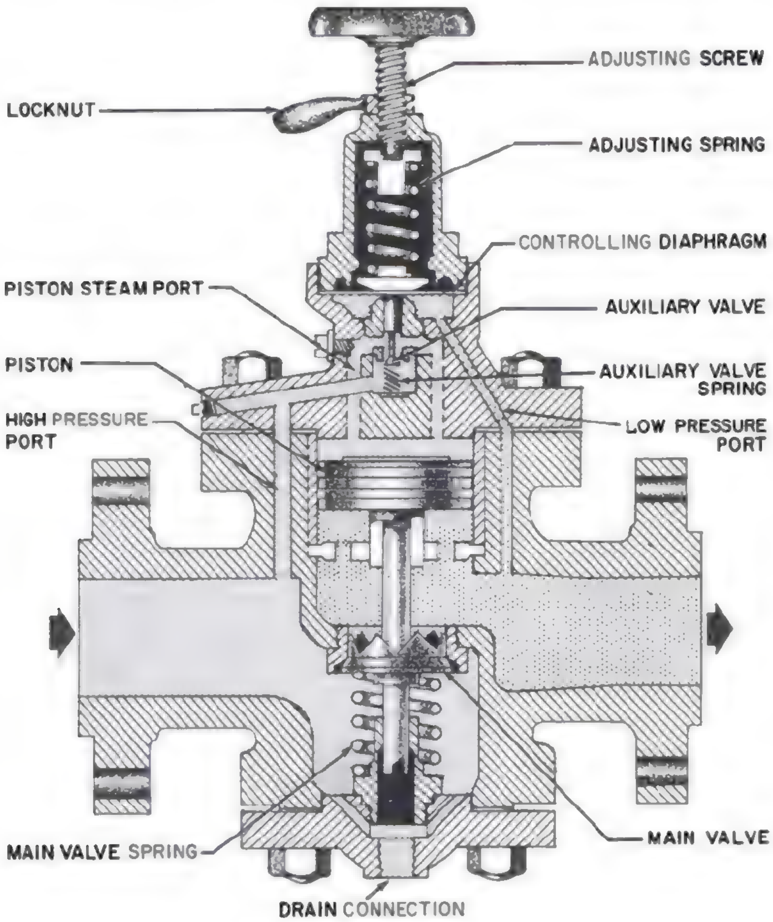

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Figure 7-9.—Spring-loaded reducing valve, showing fluid flow.

discharge pressure of steam is kept constant as long as the amount of steam used is kept within the capacity of the valve.

Another type of spring-loaded reducing valve found aboard ship, is the type usually installed in the flushing system and in the cooling water main. It is of the single-seated, direct-acting, diaphragm type illustrated in figure 7-10. Control of water passing through this valve is effected by means of a pressure difference on opposite sides of the diaphragm. The diaphragm is secured to the stem. Reduced water pressure from the valve outlet is led through an internal passage to a diaphragm chamber, below the diaphragm. An adjusting spring acts on the upper side of the diaphragm. A leather cup washer or a neoprene O-ring makes the water seal between the valve inlet and the diaphragm chamber. The water seal is located about halfway down the valve stem.

When the outlet (discharge) pressure is greater than the spring pressure, the diaphragm is forced up; because this is an upward seating valve, the upward movement of the stem tends to close the valve, thus decreasing the outlet pressure. When the outlet pressure is less than the spring pressure, the diaphragm and stem are forced down, opening the valve and increasing the outlet pressure.

When the outlet pressure and the spring pressure are equal, the diaphragm and the valve stem remain stationary and the outlet pressure remains constant. The amount of pressure applied by the spring to the top of the diaphragm can be varied by turning the adjusting screw. Turning the adjusting screw clockwise increases the pressure applied by the spring to the top of

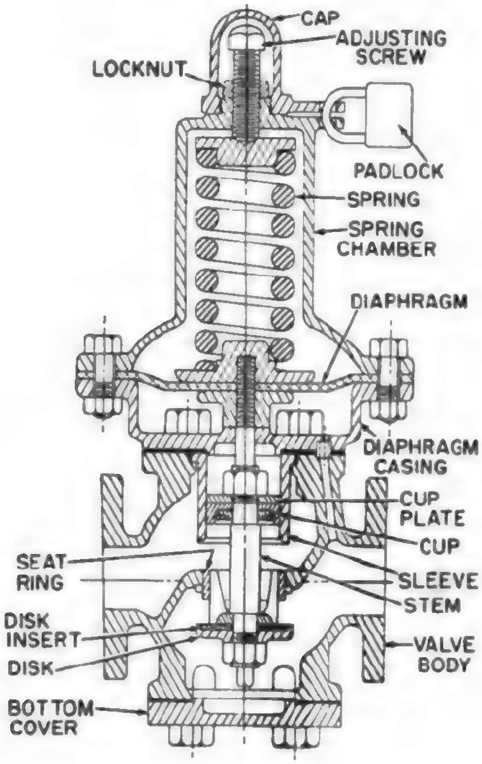

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Figure 7-10.—Spring-loaded reducing valve.

the diaphragm, thus opening the valve. Turning the adjusting nut counterclockwise decreases the amount of spring pressure on top of the diaphragm.

PNEUMATIC PRESSURE CONTROLLED REDUCING VALVES.—The pneumatic pressure controlled (or gas-loaded) reducing valve exists in two types—one type designed to regulate low temperature fluids, such as air, water, or oil (part A of fig. 7-11); and one designed to regulate high temperature fluids, as steam or hot water (part B of fig. 7-11).

Air controlled regulators operate on the principle that the pressure of an enclosed gas varies inversely as its volume. A reduction in volume results in an immediate increase in pressure—and an increase in volume results in an immediate decrease in pressure. A relatively small change in the large volume within the dome loading chamber produces only a slight pressure variation, while the slightest variation in the small volume within the actuating chamber creates an enormous change in pressure. The restricting orifice connecting these two chambers governs the rate of pressure equilization by retarding the flow of gas from one chamber to the other.

The dome loading chamber is charged with air or other compressible gases at a pressure equal to the desired reduced pressure. When the chamber is loaded, and the loading valve closed, the dome will retain its charge almost indefinitely. When the regulator is in operation, the trapped pressure within the dome passes into the actuating chamber through the small separation plate orifice and moves the large flexible diaphragm which forces the reverse acting valve off its seat. The pressure entering the regulator is then permitted to flow through the open valve into the reduced pressure line. A large pressure equalizing orifice transmits this pressure directly to the underside of the diaphragm. When the delivered pressure approximates the loading pressure in the dome, and the unbalanced forces are equalized, the valve is closed. With the slightest drop in delivered pressure, the pressure charge in the dome instantly forces the valve open. This allows air to pass through and thereby maintain the outlet pressure relatively constant.

To charge the loading chamber, back off slightly on the dome needle valve, connect up the specially furnished hand pump (either 300 or 600 psi), and fill the dome, depending upon the desired outlet pressure. If the regulator is to handle a gas, charge the dome loading chamber with this gas via the dome needle valve and the body needle valve (part A of fig. 7-11). If the regulator is to handle a liquid, the dome must be charged from an external source. Remove the plug on the dome loading chamber and connect the external source, an air bottle or an air pump. The body needle valve should be kept closed while the dome needle valve should be used to adjust the dome pressure for obtaining the desired outlet pressure.

Part B of figure 7-11 shows the construction and indicates the operating features of a pneumatic pressure controlled (gas-loaded) reducing valve designed to regulate high temperature fluids.

A rubber diaphragm is installed in the middle of the dome. The bottom of the diaphragm is separated from the bottom half of the dome by a fixed steel plate. The area immediately above the diaphragm communicates with the upper part of the dome through holes in the shrouding. The upper half of the dome carries a level of

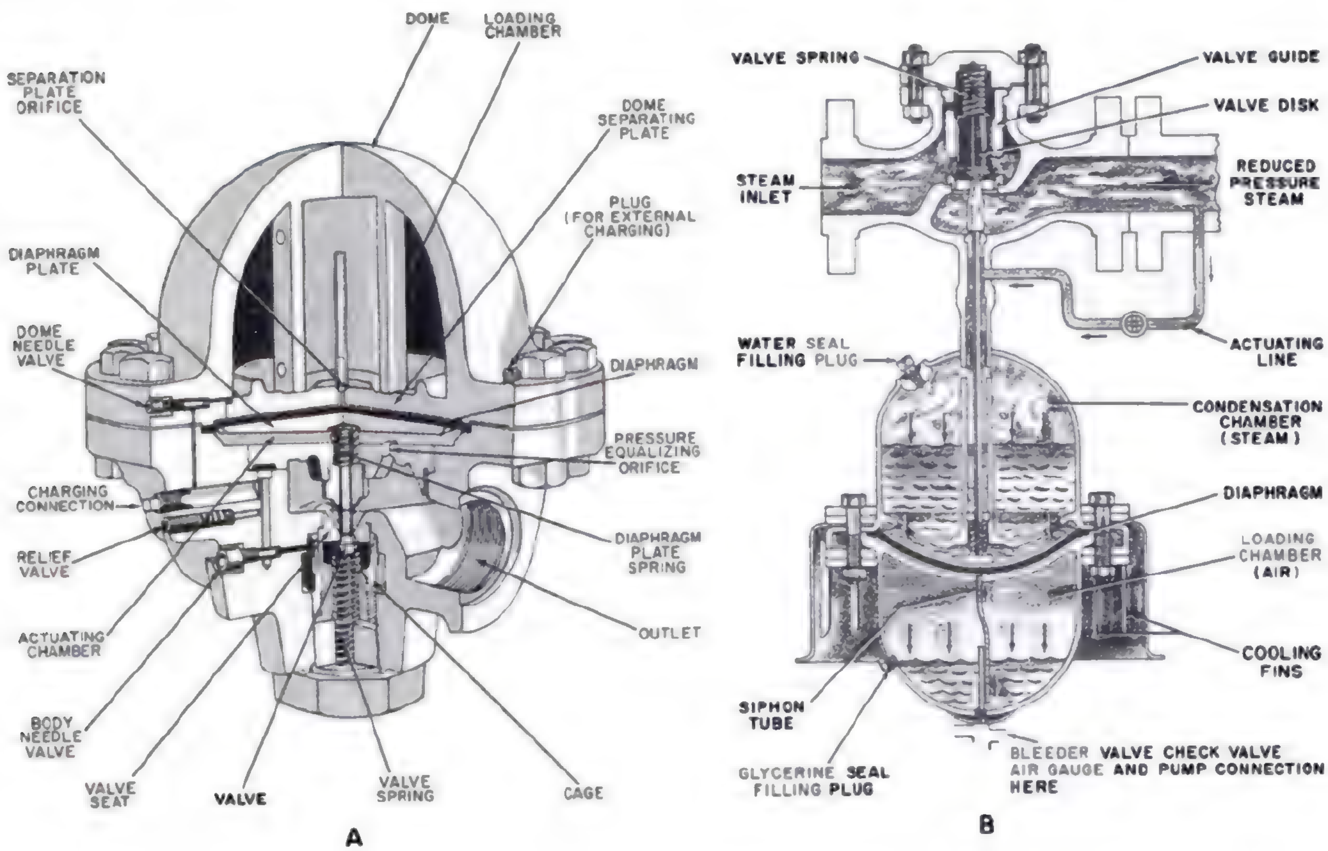

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Figure 7-11.—Pneumatic pressure controlled reducing valves. A. For low temperature fluids. B. For high temperature fluids.

water for sealing; the lower half of the dome carries a level of glycerine for sealing. The area above the glycerine is charged with air, which exerts a downward pressure on the glycerine and forces some of it to go up the tube toward the diaphragm. This pressure causes the diaphragm to move upward; and, since the stem of the valve is in contact with the diaphragm, the upward movement of the diaphragm causes the valve to open. When the valve is open, steam can pass through the valve.

From the outlet connection, an actuating line leads back to the upper part of the dome, in the manner shown in part B of figure 7-11. Steam at the reduced pressure is thus allowed to exert a force on the top of the water seal; this force is transmitted through the water and tends to move the diaphragm downward. When the pressure or steam from the actuating line exceeds the loading air pressure in the lower half of the dome, the diaphragm moves downward sufficiently to close the valve. The closing of the valve reduces the pressure of the steam on the discharge side of the valve. When the pressure on the outlet side of the valve is equal to the air pressure in the lower half of the dome, the valve takes a balanced position which allows the passage of sufficient steam to maintain that pressure.

If the steam load increases, tending to take more steam away from the valve, the outlet pressures will be momentarily reduced. Thus, the pressure of steam on top of the diaphragm becomes less than the pressure of air below the diaphragm, and the valve then opens wider to restore the outlet pressure to normal. If the demand is reduced, this causes a momentary increase in outlet pressure, and this in turn increases the pressure on top of the diaphragm above that of the air pressure below it, causing

the diaphragm to be displaced downward. The outlet pressure is again restored to normal.

Thus, theoretically, the valve should deliver a pressure of steam equal to the pressure of air pumped into the lower half of the dome. However, since the valve itself has weight and is equipped with a light spring which tends to close it, it is necessary to introduce slightly more air pressure than is theoretically required. For the higher pressure valves, about 10 psi additional air pressure is required. If air is pumped in when the valve is cold, slightly less air pressure will be needed because the air pressure will increase slightly when the valve is warmed up.

The copper shroud extending outside the dome from the center flange appears only on the high pressure valves. It is installed to allow for transmission of heat from the upper half of the dome to the atmosphere and to keep heat from passing into the lower half, where it may cause an excessive rise in the air pressure.

When the reducing valve is being put into operation, the discharge valve should be opened first. Then, if proper air pressure is in the dome, the inlet valve should be opened slowly, allowing the valve to heat up. The valve in the actuating line must be open. It may be difficult to get these valves on the line unless some steam is being bled away from the discharge side. It is desirable to have some steam leaving the valve when cutting it in. If you are careful to warm up reducing valves properly and to put them on the line slowly, no trouble should be encountered with their operation. Glycerine should always be used for the lower seal. Water should be used for the upper seal; the condensation of steam in the upper part of the dome is usually sufficient to maintain the water seal at the proper level.

Diaphragm Control Valves with Air-Operated Control Pilots

Diaphragm control valves with air-operated control pilots are being used increasingly on modern combatant ships for various pressure control applications. These valves and pilots are available in several basic designs to meet different requirements. They may be used to reduce pressure, to augment pressure, or to provide continuous regulation of pressure, depending upon the requirements of the system in which they are installed. Valves and pilots of very similar design can also be used for other services such as liquid level control and temperature control. However, the discussion here is limited to the valves and pilots used for pressure control applications.

The air-operated control pilot may be either direct acting or reverse acting. A direct acting air-operated control pilot is shown in figure 7-12. In this type of pilot, the controlled pressure—that is, the pressure from the discharge side of the diaphragm control valve—acts on top of a diaphragm in the control pilot. This pressure is balanced by the pressure exerted by the pilot adjusting spring. If the controlled pressure increases and overcomes the pressure exerted by the pilot adjusting spring, the pilot valve stem is forced down. This action causes the pilot valve to open and so increases the amount of operating air pressure going from the pilot to the diaphragm control valve. A reverse-acting pilot has a lever which reverses the pilot action. In a reverse acting pilot, therefore, an increase in controlled pressure produces a decrease in operating air pressure.

In the diaphragm control valve, operating air from the pilot acts on the valve diaphragm. The superstructure which contains the diaphragm is direct acting in some valves and reverse acting in others. If the superstructure is direct acting, the operating air pressure from the control pilot is applied to the TOP of the valve diaphragm. If the superstructure is reverse acting, the operating air pressure from the pilot is applied to the UNDERSIDE of the valve diaphragm.

Figure 7-13 shows a very simple type of direct acting diaphragm control valve, with operating air pressure from the control pilot applied to the top of the valve diaphragm. Since this is a downward seating valve, any increase in operating air pressure pushes the valve stem down and tends to close the valve.

Now look at figure 7-14. This is also a direct acting valve, with operating air pressure from the control pilot applied to the top of the valve diaphragm. But the valve shown in figure 7-14 is more complicated than the one shown in figure 7-13. The valve shown in figure 7-14 is an upward seating valve rather than a downward seating valve. Therefore, any increase in operating air pressure from the control pilot tends to OPEN this valve rather than close it.

As we have seen, the air-operated control pilot may be either direct acting or reverse acting. The superstructure of the diaphragm control valve may be either direct acting or

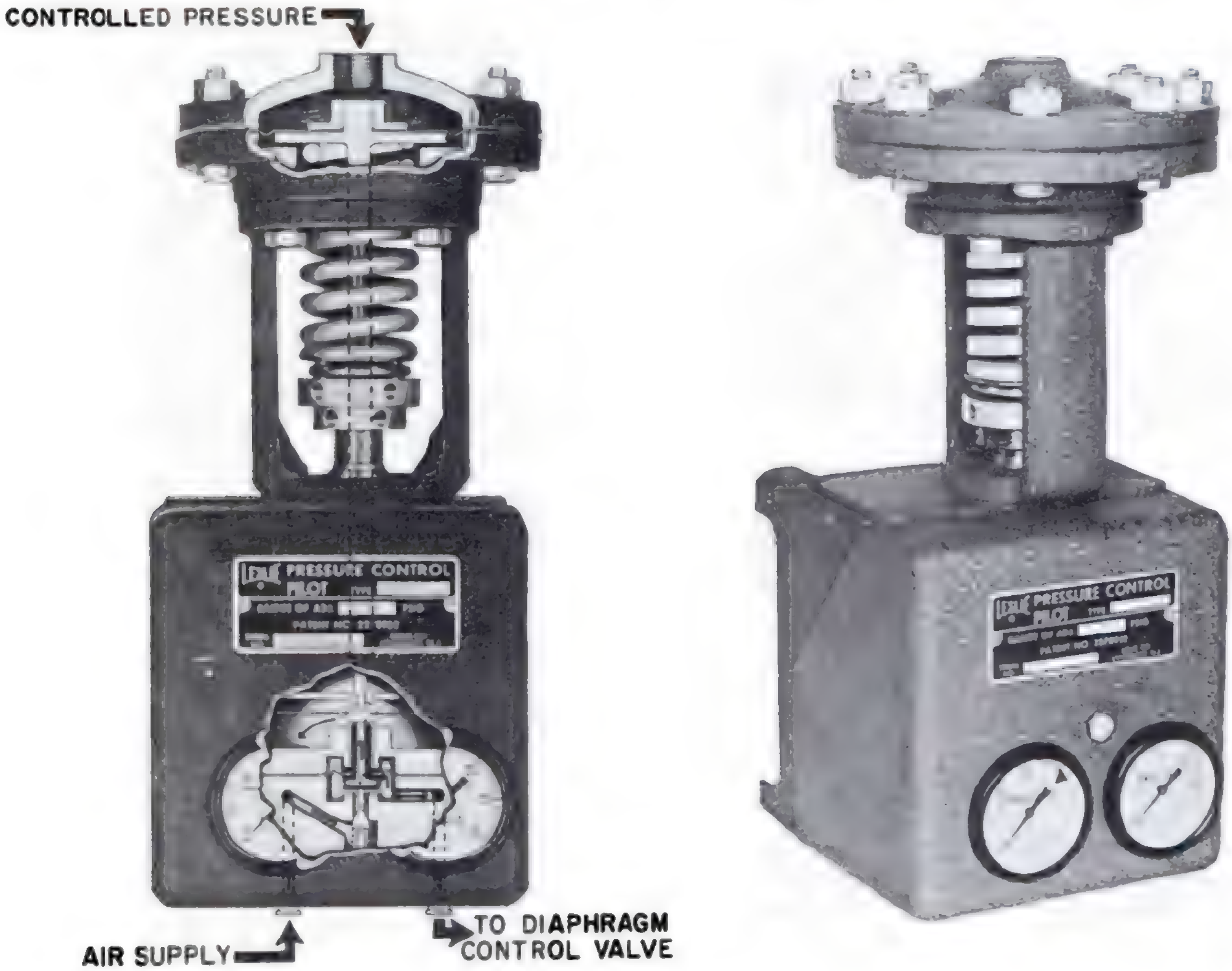
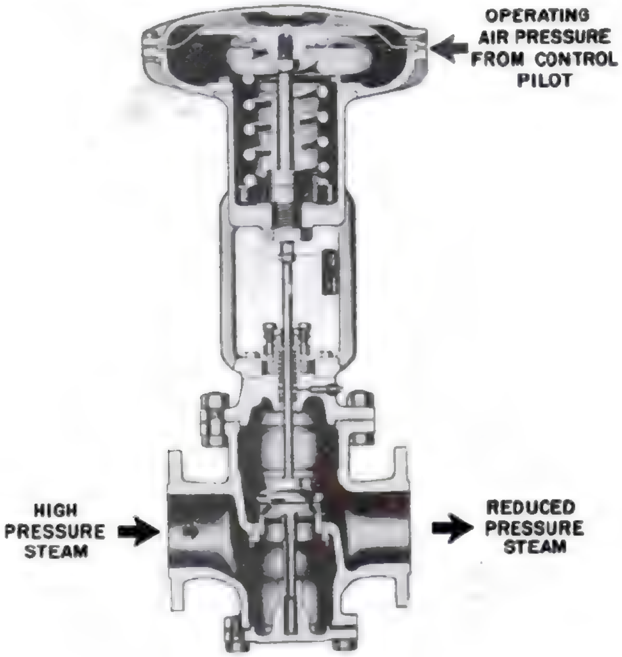


Figure 7-12.—Air operated control pilot. 38.121X

reverse acting. And the diaphragm control valve may be either upward seating or downward seating. These three factors, as well as the purpose of the installation, determine how the diaphragm control valve and its air-operated control pilot are installed in relation to each other.

To see how these factors are related, let's consider an installation in which a diaphragm control valve and its air-operated control pilot are to be used to supply reduced steam pressure. Figure 7-15 shows one arrangement that might be used. We will assume that the service requirements indicate the need for a direct acting upward seating diaphragm control valve. Can you figure out what kind of a control pilot—direct acting or reverse acting—would have to be used in this installation?

Let's try it first with a direct acting control pilot. As the controlled pressure (discharge pressure from the diaphragm control valve) increases, increased pressure would be applied to the diaphragm of the direct acting control pilot. The valve stem would be pushed down and the valve in the control pilot would be opened, thus sending an increased amount of operating air pressure from the control pilot to the top of the diaphragm control valve. The increased operating air pressure acting on the diaphragm of the valve would push the stem down and—since this is an upward seating valve—this action would OPEN the diaphragm control valve still wider. Obviously, this won't work—for this application, an INCREASE in controlled pressure must result in a DECREASE in operating air pressure. Therefore, we make a mistake



38.123X
Figure 7-13.—Diaphragm control valve, downward seating type.

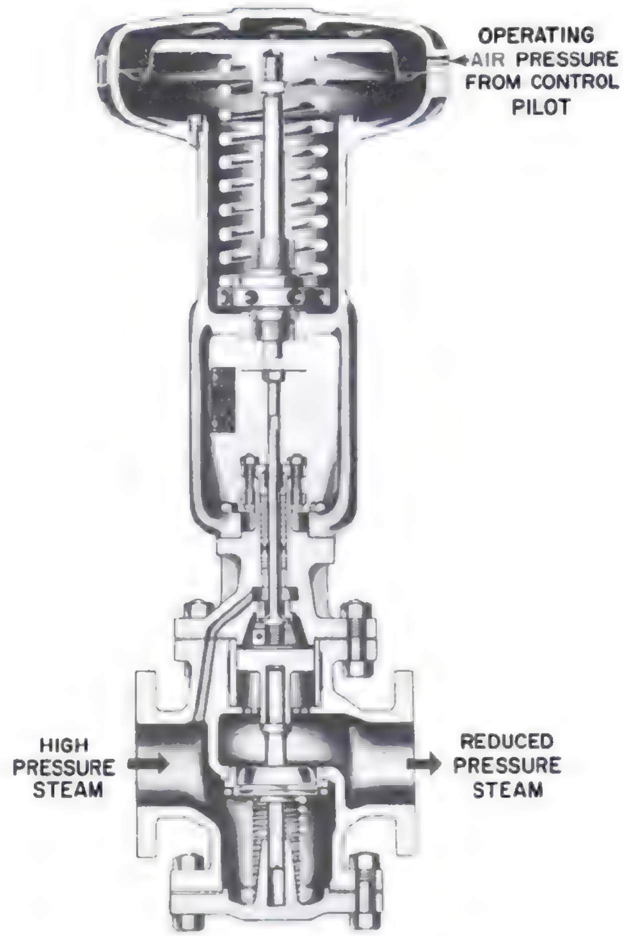
in choosing the direct acting control pilot. For this particular pressure-reducing application, we should have chosen a REVERSE ACTING control pilot.

It is not likely that you will be required to decide what type of control pilot and diaphragm control valve are needed in any particular installation. But you must know how and why they are selected so that you will not make mistakes in repairing or replacing these units.

Unloading Valves

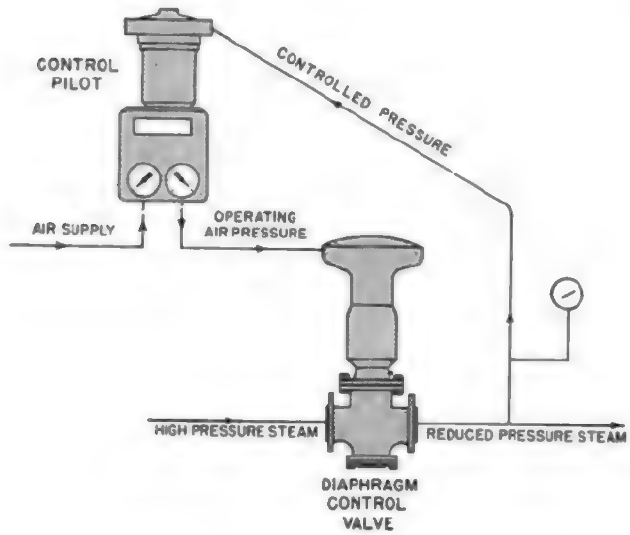
An AUTOMATIC UNLOADING VALVE (fig. 7-16) or "dumping valve," is installed at each main and auxiliary condenser. The function of these valves is to discharge steam from the auxiliary exhaust line into the condensers whenever the exhaust line pressure exceeds 15 psi.

In figure 7-16, auxiliary exhaust is piped through valve"A" to the top of the actuating valve diaphragm. When auxiliary exhaust pressure exceeds adjusting spring tension the actuating diaphragm is forced down. With the actuating diaphragm down the valve spring moves the valve disk (which is double seated) against



38.124X
Figure 7-14.—Diaphragm control valve, upward seating type.

its lower seat. With actuating valve disk on its lower seat, auxiliary exhaust is prevented from passing through valve "B" to the pressure side of the main valve diaphragm, and pressure on the main valve diaphragm is allowed to pass through valve "C" into the condenser. With pressure removed from main valve diaphragm, auxiliary exhaust acting as the main valve disk forces the main valve open. When the main valve opens the auxiliary exhaust pressure is lowered and when the auxiliary exhaust pressure is lowered the pressure on the actuating valve diaphragm is reduced. This allows the adjusting spring to move the actuating diaphragm upward and upward motion of the diaphragm moves the actuating valve disk against its upper seat.



38.125

Figure 7-15.—Arrangement of control pilot and diaphragm control valve for supplying reduced steam pressure.

With the actuating valve disk against its upper seat the auxiliary exhaust pressure passes through valves "A" and "B" and is exerted on the bottom of the main valve diaphragm moving it upward. The upward motion on the main diaphragm overcomes the main valve spring tension, moving the main valve disk up and closed.

Equalize pressure on both sides of rubber diaphragm by opening bypass valve. Use manual control valve stem to control the opening and closing of the unloading valve. To prevent loss of auxiliary exhaust pressure, always turn the manual control valve stem in until it strikes the diaphragm before opening the by-pass valve.

Thermostatically Controlled Recirculating Valves

At fractional power, or cruising power, recirculating condensate from the discharge sides of the main air ejector condenser to the main condenser is essential. Recirculating presents excessive loss of feed water (as vapor discharged from the air ejector after condenser vent) and ensures proper operation of the air ejectors at fractional power. To make recirculation automatic and to avoid excessive recirculation with attendant excessive loss of heat, most air ejector recirculating lines are fitted with thermostatically controlled valves.

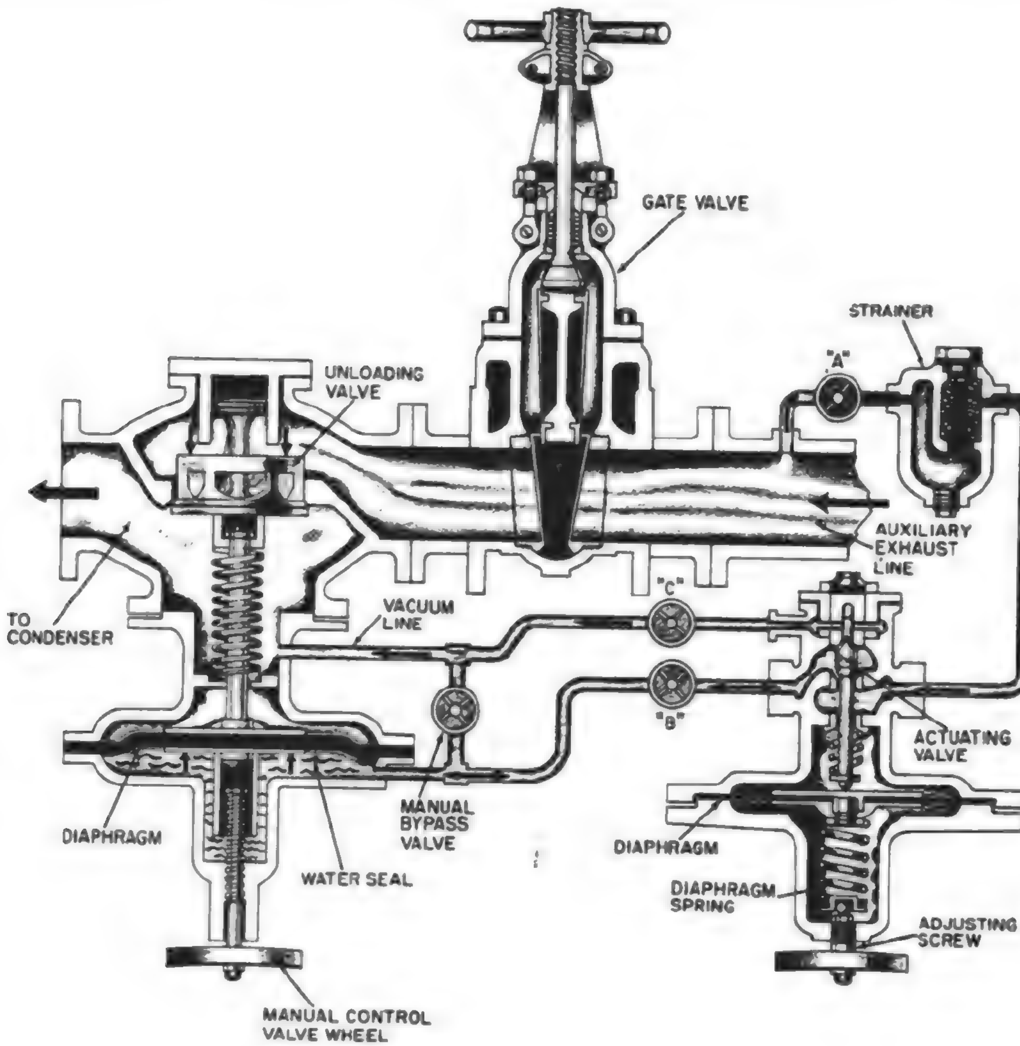
Excessive heat loss can be avoided by recirculating condensate from the discharge side of the main air ejector condenser to the main condenser. The air ejector condensers must be supplied with cooling water (condensate) during their operation. A hand-controlled valve allows bypassing of the thermostatic recirculating valve during the warming-up period. This bypass valve is also used when the thermostatic valve is inoperative.

Under normal operating conditions, recirculation to the main condenser at light loads is automatically controlled by the thermostatic recirculating valve. The thermostatic recirculating valves are actuated by the temperature of the condensate discharged from the air ejector after condenser. Rise of water temperature above the temperature at which the valve is set results in automatic opening of the valve, and recirculation of the heated water back to the condenser and through the air ejector again. The thermostatically controlled recirculating valves are adjusted through a range of approximately 40° F and should be individually set to open at the highest temperature at which the air ejectors will operate without loss of condenser vacuum, or discharge of an appreciable amount of vapor from the air ejector after condenser vent.

In the interest of economy, the thermostatically controlled valve should be kept in good condition and properly set. Under all normal operating conditions, the manual bypasses should be kept closed. The control bulbs of the valves should be located in the condensate line as close as possible to the after condenser discharge, or preferably (when space is available), within the last pass of the air ejector after condenser water chest.

Figure 7-17 illustrates a thermostatic recirculating valve. Failure of the valve to maintain the cooling water at the desired temperature is an indication of improper adjustment. It may also be an indication that the thermostatic elements of the valve are leaking, or that some other portion of the valve has failed.

The main cause for improper adjustment of the valve is the lack of instructions for the proper adjustment procedure. Operating personnel should become familiar with the procedure for adjustment of this type of valve; it is recommended that they consult the manufacturer's instructions.



47.61X
Figure 7-16.—Automatic unloading valve.

Briefly, the adjustment consists of changing the tension of the spring which opposes the action of the thermostatic bellows. An increase in spring tension will require a higher temperature to be reached before the valve will act to direct a greater portion of the condensate to the condenser.

However, when placing a new valve in service, steps must be taken to ensure that the valve will open and close at the recommended temperatures.

When the valve is completely installed in accordance with correct maintenance procedures, the condensate system should be placed in operation. When the condensate temperature reaches the desired level, turn the adjusting wheel (adjusting assembly) until the poppet valve just begins to leave its seat, as shown by the downward movement of the mark on the valve stem.

Valves adjusted in accordance with this procedure will normally maintain the temperature of the water at the thermostatic bulb between the temperature determined and a temperature approximately 20° F higher. This 20° F difference is the temperature rise required to cause the poppet valve to move through the necessary travel.

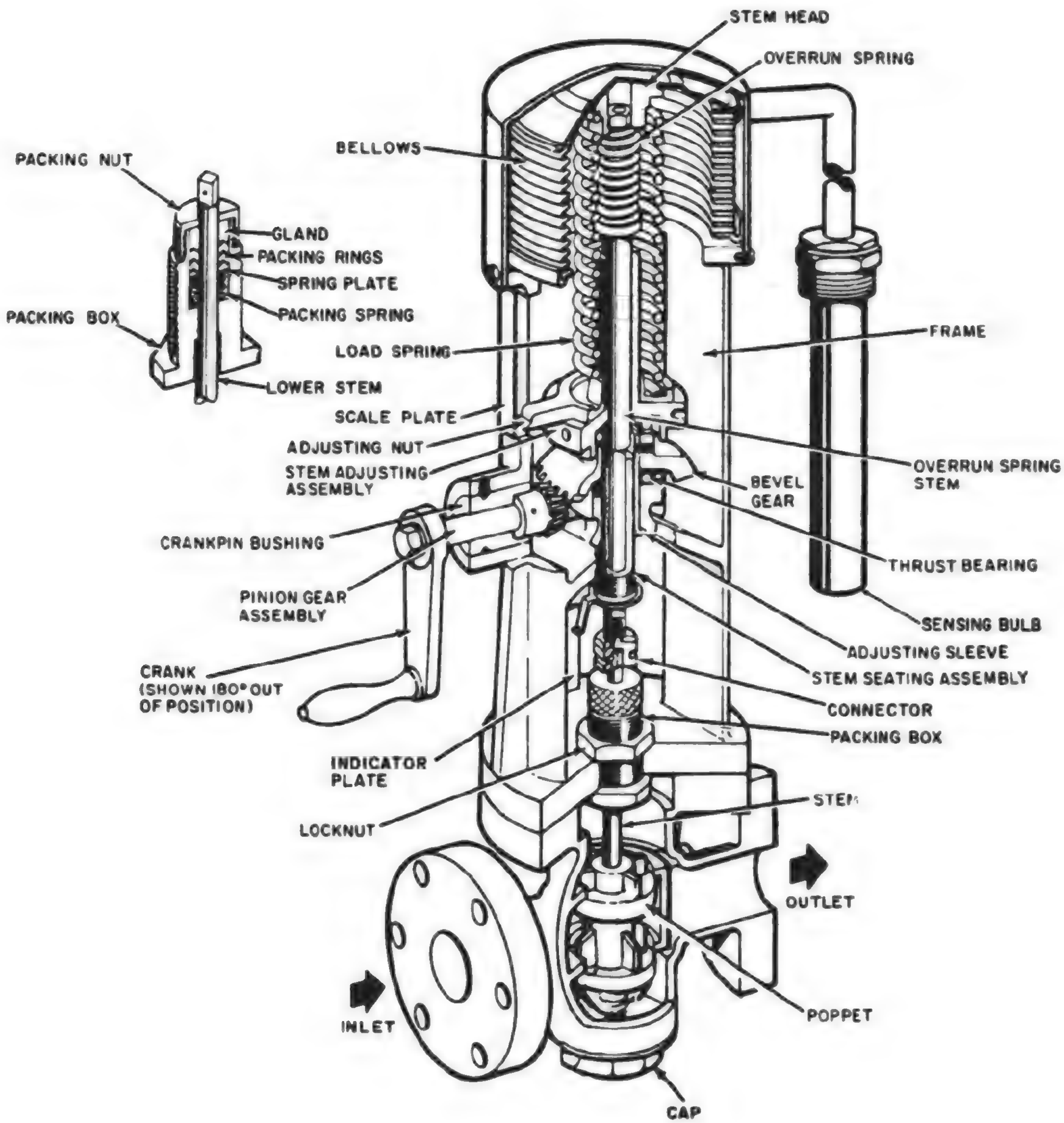


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Figure 7-17.—Thermostatic recirculating valve.

VALVE MANIFOLDS

Sometimes it is necessary to take suction from any one of many sources, and discharge to another unit or units of either the same or another group. A valve manifold is used for this type of operation. An example of such a manifold (fig. 7-18) is the fuel oil filling and transfer system, where provision must be made for the transfer of oil from any tank to any other tank, to the service system, or to another ship. If, for example, the purpose is to transfer oil from tank No. 1 to tank No. 4, the filling valve for tank No. 4 and the discharge valve from tank No. 1 are opened, and all other valves closed. Fuel oil can now flow from tank No. 1, through the suction line, through the pump, through the discharge valve, and into tank No. 4. The manifold filling valves are often of the stop-check type, to prevent draining of pumps when they are stopped.

REMOTE OPERATED VALVES

Remote operating gear is installed to provide a means of operating certain valves from distant stations. Remote operating gear may be mechanical, hydraulic, pneumatic, or electric.

Some remote operating gear for valves is used in normal operation of valves. For example, the main engine throttle valves are opened and closed by a reach rod or series of reach rods and gears. Reach rods may be used to operate engineroom valves in instances where the valves are difficult to reach from operating stations.

Other remote operating gear is installed as emergency equipment. Some split-plant valves, main drainage valves, and main condenser injection and overboard valves are equipped with remote operating gear. These valves can be operated normally or in an emergency they may be operated from remote stations. Remote operating gear also includes a valve position indicator to show whether the valve is open or closed.

MAINTENANCE AND REPAIR OF VALVES

Preventive maintenance is the best way to extend the service life of valves and fittings. As soon as you observe a leak, determine the cause, then apply the proper corrective maintainance. This maintenance may be as simple as tightening a packing nut or a gland. A leaking flange joint may need only to have the bolts tightened or to have a new gasket or O-ring inserted. Dirt and scale, if allowed to collect, can ultimately cause leakage. Loose hangers permit sections of a line to sag, and the weight of the pipe and the fluid in these sagging sections may strain joints to the point of leakage.

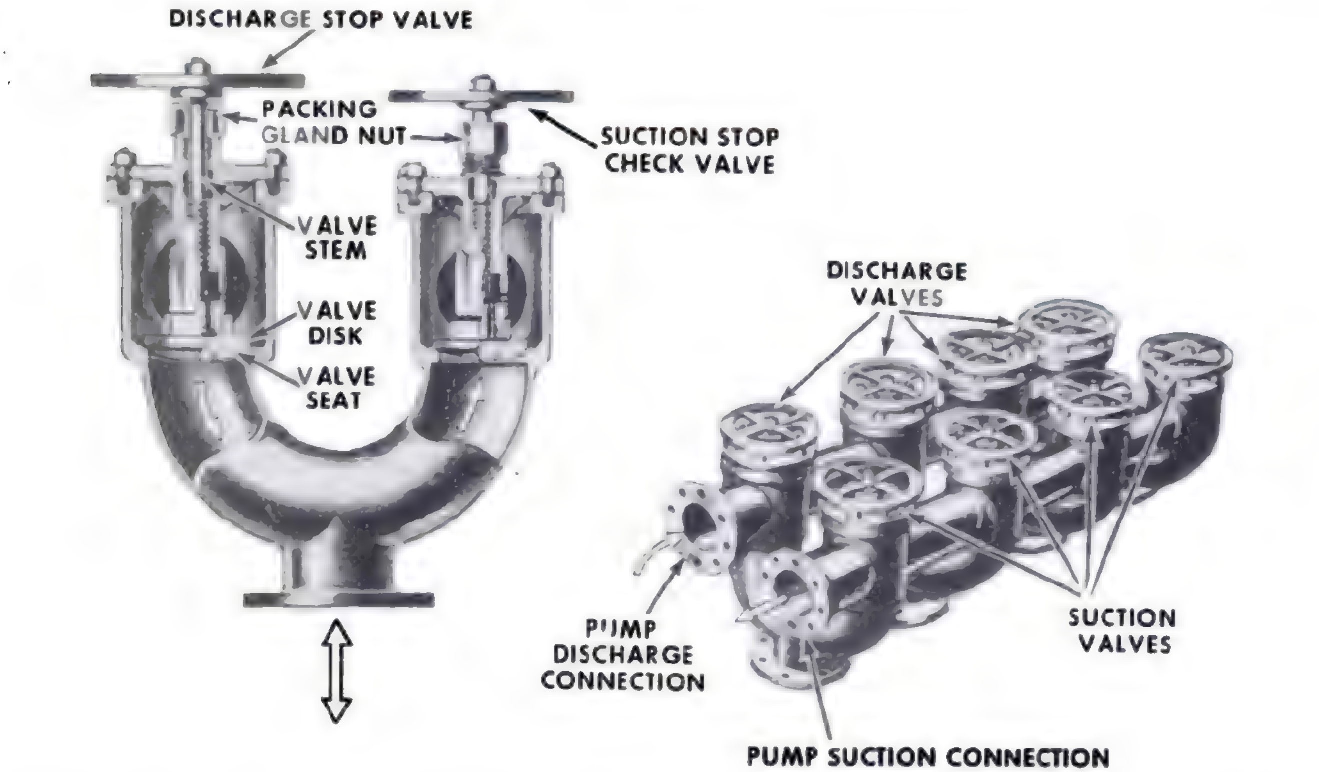
Whenever you are going to install a valve, make sure that you know the function that the valve is to perform—that is, whether it must prevent back flow, start flow, stop flow, regulate flow, or regulate pressure. Inspect the valve body for the information that is stamped upon it by the manufacturer: type of system (oil, water, gas); operating pressure; direction of flow; and other information.

You should also know the operating characteristics of the valve, the metal from which it is made, and the type of end connection with which it is fitted. Operating characteristics and the material are factors that affect the length and kind of service that a valve will give; end connections indicate whether or not a particular valve is suited to the installation.

Valves should be installed in accessible places, and with enough headroom to allow for full operation. Install valves with stems pointing upward, if possible. A stem position between straight up and horizontal is acceptable, but avoid the inverted position (stem pointing downward). When the valve is installed in the latter position, sediment will collect in the bonnet and score the stem. In a line that is subject to freezing temperatures, liquid that is trapped in the valve bonnet may freeze and rupture it.

Globe valves may be installed with pressure either above the disk or below the disk, depending upon which method will be best for the operation, protection, maintenance, and repair of the machinery served by the system. The question of what would happen if the disk became detached from the stem is a major consideration in determining whether pressure should be above the disk or below it. If you are required to install a globe valve, be SURE to check the blueprints for the system to see which way the valve must be installed. Very serious casualties can result from installing a valve with pressure above the disk when it should be below the disk, or below the disk when it should be above.

Valves which have been in constant service over a long period of time will eventually require gland tightening, repacking, or a complete overhaul of all parts. If it is known that a valve is



47.63X

Figure 7-18.—Valve manifold showing cutaway view of the valves and typical combination of suction and discharge valves.

not doing the job for which it is intended, the valve should be dismantled and all parts inspected. All defective parts must be repaired or replaced.

The repair of globe valves (other than routine renewal of packing) is generally limited to refinishing the seat and disk surfaces. When this work is being done, there are certain precautions that should be observed.

When refinishing the valve seat, no more material should be removed than is necessary. Valves that do not have replaceable valve seats can be refinished only a limited number of times.

Before you do any repair to the seat and disk of a globe valve, check the valve disk to make certain it is secured rigidly to and is square on the valve stem. Also, check to be sure that the stem is straight. If the stem is not straight, the valve disk cannot seat properly. The valve seat and valve disk should be carefully inspected for evidence of wear, for cuts on the seating area, and for improper fit of the disk to the seat. If the disk and the seat appear to be in good condition, they should be spotted-in to find out whether they actually are in good condition.

Spotting-in Valves

The method used to determine visually whether or not the seat and the disk make good contact with each other is called spotting-in. To spot-in a valve seat, first apply a thin coating of Prussian blue evenly over the entire machined face surface of the disk. Then insert the disk into the valve and rotate it a quarter turn, using a light downward pressure. The Prussian blue will adhere to the valve seat at those points where the disk makes contact. Figure 7-19 shows what a correct seat looks like when it is spotted-in; it also shows what various kinds of imperfect seats look like.

After you have noted the condition of the seat surface, wipe all the Prussian blue off the disk face surface. Apply a thin, even coat of blue to the contact face of the seat, and again place the disk on the valve seat and rotate the

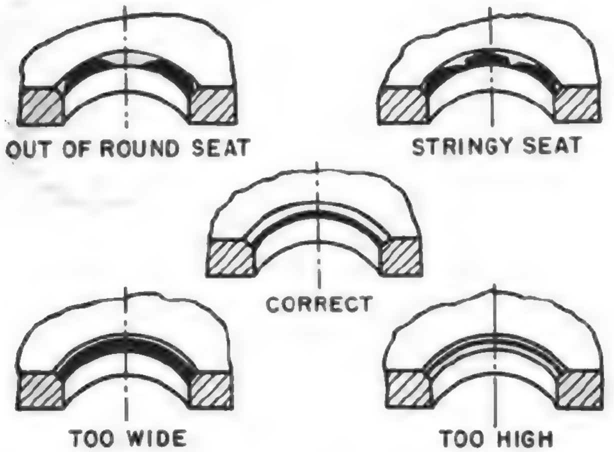


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Figure 7-19.—Examples of spotted-in valve seats.

disk a quarter of a turn. Examine the resulting blue ring on the valve disk. The ring should be unbroken and of uniform width. If the blue ring is broken in any way, the disk is not making a proper fit.

Grinding-in Valves

The manual process used to remove small irregularities by grinding together the contact surfaces of the seat and disk is called grinding-in. Grinding-in should not be confused with refacing processes in which lathes, valve reseating machines, or power grinders are used to recondition the seating surfaces.

To grind-in a valve, first apply a small amount of grinding compound to the face of the disk. Then insert the disk into the valve and rotate the disk back and forth about a quarter of a turn; shift the disk-seat relationship from time to time so that the disk will be moved gradually, in increments, through several rotations. During the grinding process, the grinding compound will gradually be displaced from between the seat and disk surfaces; therefore, it is necessary to stop every minute or so to replenish the compound. When you do this, wipe both seat and the disk clean before applying the new compound to the disk face.

When it appears that the irregularities have been removed, spot-in the disk to the seat in the manner previously described.

Grinding-in is also used to follow up all machining work on valve seats or disks. When the valve seat and disk are first spotted-in after they have been machined, the seat contact will be very narrow and will be located close to the bore. Grinding-in, using finer and finer compounds as the work progresses, causes the seat contact to become broader. The contact area should be a perfect ring covering approximately one-third of the seating surface.

Be careful to avoid overgrinding a valve seat or disk. Overgrinding tends to produce a groove in the seating surface of the disk; it also tends to round off the straight, angular surface of the disk. Machining is the only process by which overgrinding can be corrected.

Lapping Valves

When a valve seat contains irregularities that are slightly larger than can be satisfactorily removed by grinding-in, the irregularities can be removed by lapping. A cast-iron tool (LAP) of exactly the same size and shape as the valve disk is used to true the valve seat surface. Two lapping tools are shown in figure 7-20.

The most important points to remember while using the lapping tool are:

1. Do not bear heavily on the handle of the lap.
2. Do not bear sideways on the handle of the lap.
3. Change the relationship between the lap and the valve seat so that the lap will gradually and slowly rotate around the entire seat circle.
4. Keep a check on the working surface of the lap. If a groove develops, have the lap refaced.
5. Always use clean compound for lapping.
6. Replace the compound often.
7. Spread the compound evenly and lightly.
8. Do not lap more than is necessary to produce a smooth, even seat.
9. Always use a fine grinding compound to finish the lapping job.
10. Upon completion of the lapping job, spot-in and grind-in the disk to the seat.

Only approved abrasive compounds should be used for reconditioning valve seats and disks. Compounds for lapping and grinding valve disks and seats are supplied in various grades. A coarse grade compound is used when extensive corrosion or deep cuts and scratches are found on the disks and seats. A compound of medium grade is used to follow up the coarse grade; it may also be used to start the reconditioning

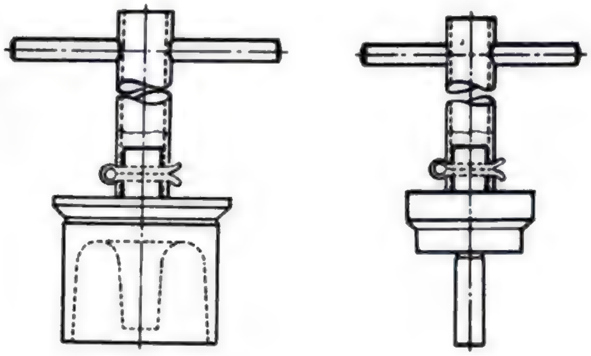

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Figure 7-20.—Lapping tools.

process on valves which are not too severely damaged. A fine grade compound should be used when the reconditioning process nears completion. A microscopic-fine grade is used for finish lapping and for all grinding-in.

Refacing Valves

Badly scored valve seats must be refaced in a lathe, with a power grinder, or with a valve reseating machine. The lathe, rather than the reseating machine, should be used for refacing all valve disks and all hard surfaced valve seats. Work that must be done on a lathe or with a power grinder should be turned over to shop personnel. The discussion here applies only to refacing valve seats with the reseating machine shown in figure 7-21.

To reface a valve seat with a reseating machine, attach the correct 45° facing cutter to the reseating machine. With a fine file, remove all high spots on the surface of the flange upon which the chuck jaws must fit. Note that a valve reseating machine can be used ONLY with a valve in which the inside of the bonnet flange is bored true with the valve seat; if this condition does not exist, the valve must be reseated in a lathe, and the inside flange bored true.

Before placing the chuck in the valve opening, open the jaws of the chuck wide enough to rest on the flange of the opening. Now tighten up on the jaws lightly so that the chuck securely grips the sides of the valve opening, tap the chuck down with a wooden mallet until the jaws reset firmly and squarely on the flange, and then tighten up further on the jaws.

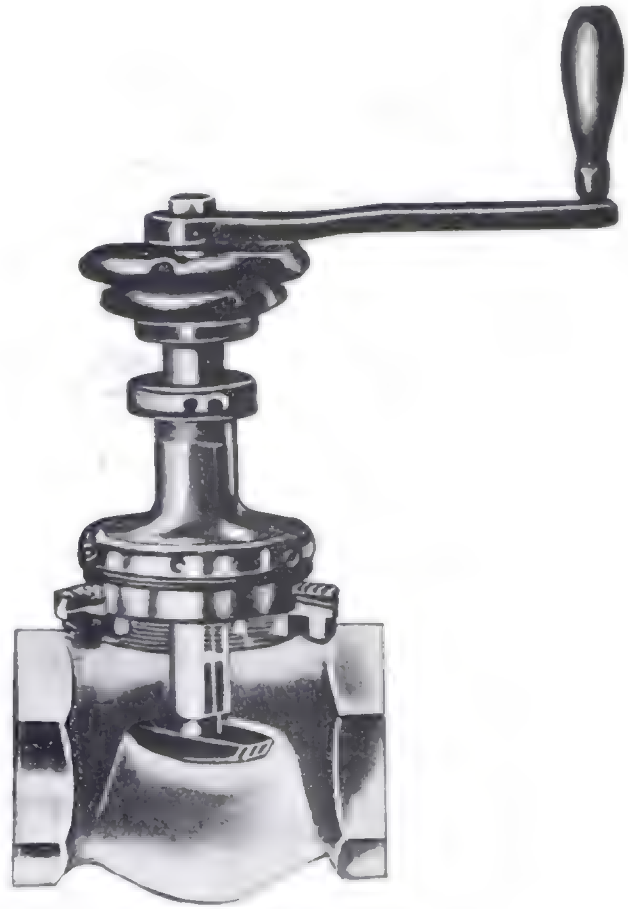

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Figure 7-21.—Valve reseating machine.

Adjust and lock the machine spindle in the cutting position and start the cutting by turning slowly on the crank. Feed the cutter slowly so that very light shavings are taken. After some experience, you will be able to know by the feel whether or not the tool is cutting evenly all around. Remove the chuck to see if enough metal has been removed.

Be sure that the seat is perfect. Then remove the cutter and face off the top part of the seat with a flat cutter. Dress the seat down to the proper dimensions, as follows:

WIDTH OF SEAT	SIZE OF VALVE
1/16 inch	1/4 to 1 inch
3/32 inch	1 1/4 to 2 inches
1/8 inch	2 1/2 to 4 inches
3/16 inch	4 1/2 to 6 inches

After the refacing, grind-in the seat and disk. Spot-in as necessary to check the work. A rough method of spotting-in that may be used is to place pencil marks at intervals of about 1/2 inch on the bearing surface of the seat or disk; then place the disk on the seat and rotate the disk about a quarter of a turn. If the pencil marks in the seating area rub off, the seating is considered satisfactory.

Repacking Valve Stuffing Boxes

If the stem of a valve (particularly a globe valve) is in good condition, stuffing box leaks can usually be stopped by setting up on the gland. If this does not stop the leakage, repack the stuffing box. The gland must not be set up on or packed so tightly that the stem binds. If the leak persists, a bent or scored valve stem may be the cause of the trouble.

Coils (string) and rings are the common forms of packing used in valves. (Additional information concerning packing is discussed later in this chapter.) The form of packing to be used in repacking a particular valve depends in part on the size of the packing required. In general, rings are used in valves that require packing larger than 1/4 inch. When a smaller size of packing is required, string packing is generally used.

To repack a stuffing box, place successive turns of the packing material around the valve stem. If you are using string packing, coil it around the valve stem and bevel off the ends to make a smooth seating for the bottom of the gland. Then put on the gland and set up on the gland nut. To keep string packing from folding back when the gland is tightened, wind the packing in the direction in which the gland nut is to be turned. When using ring packing, be sure that the joints of the successive rings are staggered.

Steam Reducing Valves, Internal Pilot Actuated

Steam reducing valves, internal pilot actuated, should be isolated, removed, and disassembled in accordance with manufacturer's instructions. When valves are disassembled, the most important preventive maintenance procedures are as follows:

1. Clean the parts with an inflammable solvent. Remove foreign materials with crocus cloth, except for nonmetallic parts. Check the main and pilot valves to ensure that they move freely in their guides and are properly seated.
2. Clean the guide stems and bushings with crocus cloth.
3. Inspect the guide stems at the junction with the valve disk by using dye penetrant for fatigue cracks. Replace if necessary.
4. Inspect the seating surfaces for damage. Fine cracks or small pits can be removed by handlapping the disk to seat with an appropriate, very mild lapping compound. If the seating surfaces are badly wire-drawn, scored, or pitted, replace the disk and seat or reface the seating surfaces.
5. Clean the cylinder liner, where applicable, with crocus or very mild aluminum oxide cloth. Badly scored liners should be rehoned or replaced. In honing, an I. D. variation of 0.005 inch over the standard dimension shown on the drawing is permissible.
6. Inspect the piston seals for damage and if piston rings are used, they should move and expand freely in grooves; replace if damaged or distorted.
7. Hand lap the pilot valve and clean the guiding surfaces with crocus cloth.
8. Run soft copper wire through control ports to clean out dirt, and blow out with compressed air.
9. Inspect all flange seating surfaces for signs of wire drawing. Remachine if necessary.
10. Check the pilot valve stem clearance after tightening the pilot valve seat. Refer to the applicable technical manual for the prescribed procedure. Remember that the pilot valve seat must be tight. Do not loosen to meet depth dimension.
11. Wire brush and wipe clean all flange bolting and apply a light coat of high temperature lubricant.

To reassemble steam reducing valves, internal pilot actuated, install a new pilot valve diaphragm, and, using new gaskets reassemble the valve.

The installation and adjustment procedure for steam reducing valves, internal pilot actuated, is as follows:

1. Reinstall the valve in line.
2. Back off adjusting screw to release compression on adjusting spring.
3. Open the stop valve in the remote impulse line, where applicable.

4. Slowly open the inlet stop valve wide. On high capacity valves, use the bypass to bring the system up to slightly under the desired pressure setting.

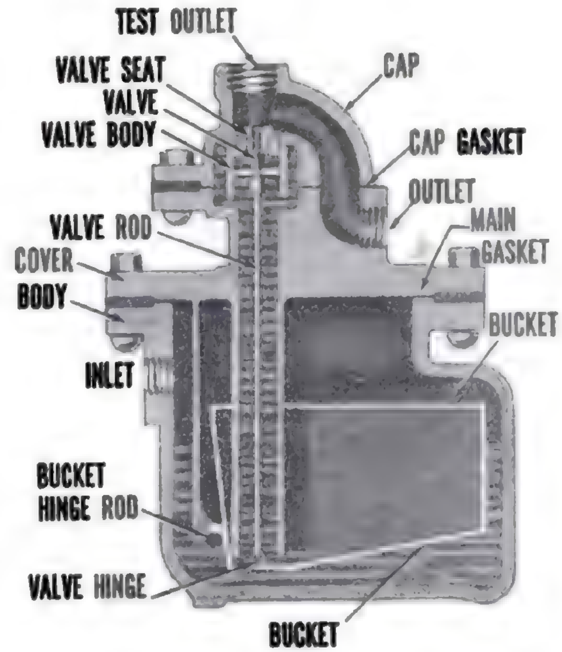
5. Fully open any stop valves between the regulator outlet and the discharge pressure gage. (The gage should be ahead of the outlet stop valve.) Partially open the outlet stop valve. Where possible, the flow through the regulator should be throttled by using a valve downstream of the discharge pressure gage so that the regulator may be set at a low flow condition.

6. Slowly turn down on the adjusting screw until the desired downstream pressure is shown on the discharge pressure gage.

7. Secure the bypass valve.

8. Slowly bring the regulator up to full flow and check regulation.

9. To change the outlet pressure, turn the adjusting screw clockwise to increase and counterclockwise to decrease the pressure.



11.325X
Figure 7-22.—Bucket type steam trap.

STEAM TRAPS

Steam traps are installed in steam lines to drain condensate from the lines without allowing the escape of steam. There are many different designs of steam traps; some are suitable for high pressure use and others for low pressure use. Some types of steam traps that are used in the Navy are described in this section.

MECHANICAL STEAM TRAPS

Mechanical steam traps in common use include ball float traps and bucket type traps. The ball float type of trap is described and illustrated in Fireman, NAVPERS 10520-D.

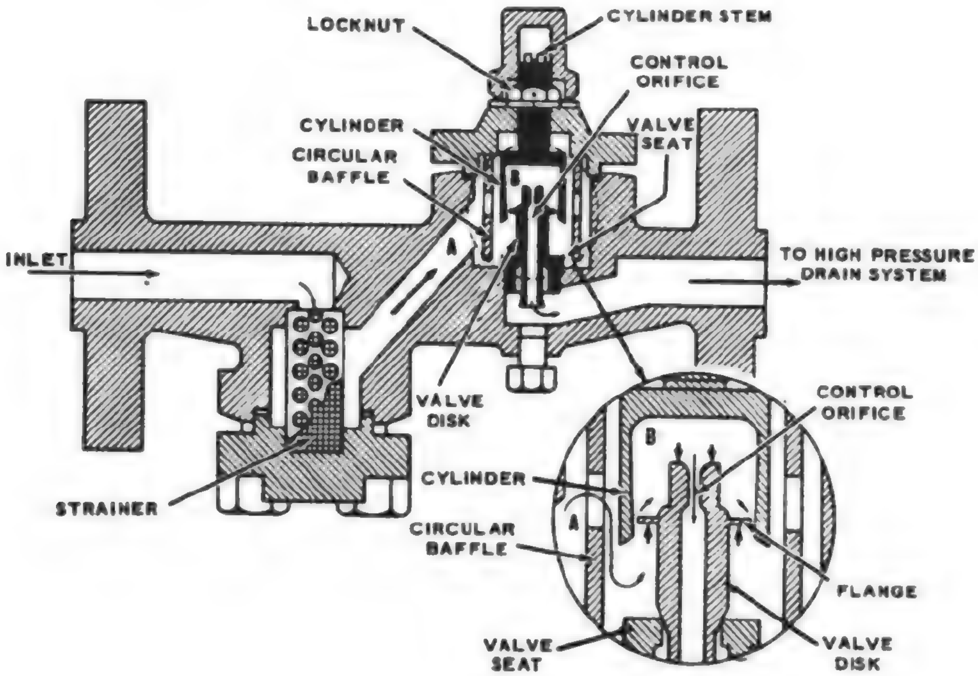
The operation of the bucket type steam trap shown in figure 7-22 is controlled by the condensate level in the trap body. The bucket floats as condensate enters the trap body. The valve is connected to the bucket in such a way that the valve closes as the bucket rises. As condensate continues to flow into the trap body, the valve remains closed until the bucket is full. When the bucket is full, it sinks and thus opens the valve. The valve remains open until enough condensate has blown out to allow the bucket to float, thus closing the valve.

THERMOSTATIC STEAM TRAPS

There are several types of thermostatic steam traps. In general, these traps are more compact and have fewer moving parts than most mechanical steam traps. The operation of a bellows type thermostatic trap (illustrated in Fireman, NAVPERS 10520-D) is controlled by expansion of the vapor of a volatile liquid, enclosed in a bellows type element. Steam enters the trap body and heats the volatile liquid in the sealed bellows, thus causing expansion of the bellows. The valve is attached to the bellows in such a way that the valve closes when the bellows expands. The valve remains closed, trapping steam in the trap body. As the steam cools and condenses, the bellows cools and contracts, thereby opening the valve and allowing the condensate to drain.

IMPULSE STEAM TRAPS

Impulse steam traps of the type shown in figure 7-23 are commonly used in steam drain collecting systems aboard ship. Steam and condensate pass through a strainer before entering



38.126
Figure 7-23.—Impulse steam trap.

the trap. A circular baffle keeps the entering steam and condensate from impinging on the cylinder or on the disk.

The impulse type of steam trap depends for its operation upon the fact that hot water under pressure tends to flash into steam when the pressure is reduced. In order to understand how this principle is utilized, let's consider the arrangement of parts shown in figure 7-23 and see what happens to the flow of condensate under various conditions.

The only moving part in the steam trap is the disk. This disk is rather unusual in design. Near the top of the disk there is a flange that acts as a piston. As you can see in figure 7-23, the working surface above the flange is larger than the working surface below the flange; the importance of having this larger effective area above the flange is brought out later in this discussion.

A control orifice runs through the disk from top to bottom, being considerably smaller at the top than at the bottom. The bottom part of the disk extends through and beyond the orifice in the seat. The upper part of the disk (including the flange) is inside a cylinder. The cylinder tapers inward, so the amount of clearance between the flange and the cylinder varies according to the position of the valve. When the valve is open, the clearance is greater than when the valve is closed.

When the trap is first cut in, pressure from the inlet (chamber A) acts against the underside of the flange and lifts the disk off the valve seat. Condensate is thus allowed to pass out through the orifice in the seat; and, at the same time, a small amount of condensate (called CONTROL FLOW) flows up past the flange and into chamber B. The control flow discharges through the control orifice, into the outlet side of the trap, and the pressure in chamber B remains lower than the pressure in chamber A.

As the line warms up, the temperature of the condensate flowing through the trap increases. The reverse taper of the cylinder varies the amount of flow around the flange until a balanced position is reached in which the total force exerted above the flange is equal to the total force exerted below the flange. It is important to note that there is still a PRESSURE DIFFERENCE between chamber A and chamber B. The FORCE is equalized because the effective area above the flange is larger than the effective area below the flange. The difference in working

area is such that the valve maintains an open, balanced position when the pressure in chamber B is 86 percent of the pressure in chamber A.

As the temperature of the condensate approaches its boiling point, some of the control flow going to chamber B flashes into steam as it enters the low pressure area. Since the steam has a much larger volume than the water from which it is generated, pressure is built up in the space above the flange (chamber B). When the pressure in this space is greater than 86 percent of the inlet pressure, the force exerted on the top of the flange pushes the entire disk downward and so closes the valve.

With the valve closed, the only flow through the trap is past the flange and through the control orifice. When the temperature of the condensate entering the trap drops slightly, condensate enters chamber B without flashing into steam. Pressure in chamber B is thus reduced to the point where the valve opens and allows condensate to flow through the orifice in the valve seat. Thus the entire cycle is repeated.

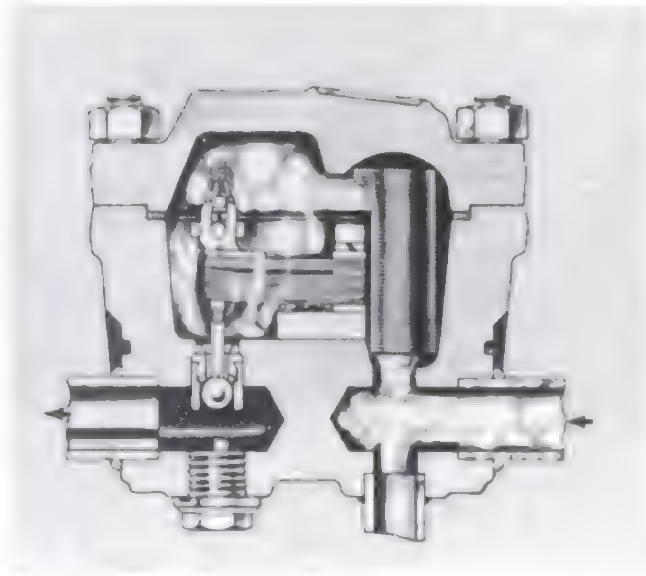
With a normal condensate load, the valve opens and closes at frequent intervals, discharging a small amount of condensate at each opening. With a heavy condensate load, the valve remains wide open and allows a heavy, continuous discharge of condensate.

BIMETALLIC STEAM TRAPS

Bimetallic steam traps of the type shown in figure 7-24 are used on many ships to drain condensate from main steam lines, auxiliary steam lines, and other steam lines. The main working parts of this steam trap are a segmented bimetallic element and a ball-type check valve.

The bimetallic element consists of several bimetallic strips fastened together in a segmented fashion, as shown in figure 7-24. One end of the bimetallic element is fastened rigidly to a part of the valve body; the other end, which is free to move, is fastened to the top of the stem of the ball-type check valve.

Line pressure acting on the check valve tends to keep the valve open. When steam enters the trap body, the bimetallic element expands unequally because of the differential response to temperature of the two metals; the bimetallic element deflects upward at its free end, thus moving the valve stem upward and closing the valve. As the steam cools and condenses, the bimetallic element moves downward, toward the horizontal position, thus opening the valve and allowing some condensate to flow out through the valve. As the flow of condensate begins, an unbalance of line pressure across the valve is created; since the line pressure is greater on the upper side of the ball of the check valve, the valve now opens wide and allows a full capacity flow of condensate.



147.104X
Figure 7-24.—Bimetallic steam trap.

ORIFICE-TYPE STEAM TRAPS

Aboard ship, continuous-flow steam traps of the orifice type are used in some constant service steam systems, oil heating steam systems, ventilation preheaters, and other systems or services in which condensate forms at a fairly steady rate. Orifice-type steam traps are NOT suitable for services in which the condensate formation is not continuous.

There are several variations of the orifice-type steam trap, but all types have one thing in common—they contain no moving parts. One or more restricted passageways or orifices allow condensate to trickle through but do not allow steam to flow through. In addition to the orifices, some orifice-type steam traps have baffles.

MAINTENANCE AND REPAIR OF STEAM TRAPS

A strainer is installed just ahead of each steam trap. This strainer must be kept clean and in good condition to keep scale and other foreign matter from getting into the trap. Scale and sediment can clog the working parts of a steam trap and seriously interfere with the working of the trap.

Steam traps that are not working properly can waste a large amount of steam and can cause operating troubles in vital systems and machinery. A quarterly check on the operation of all steam traps is required by the Naval Ship Systems Command.

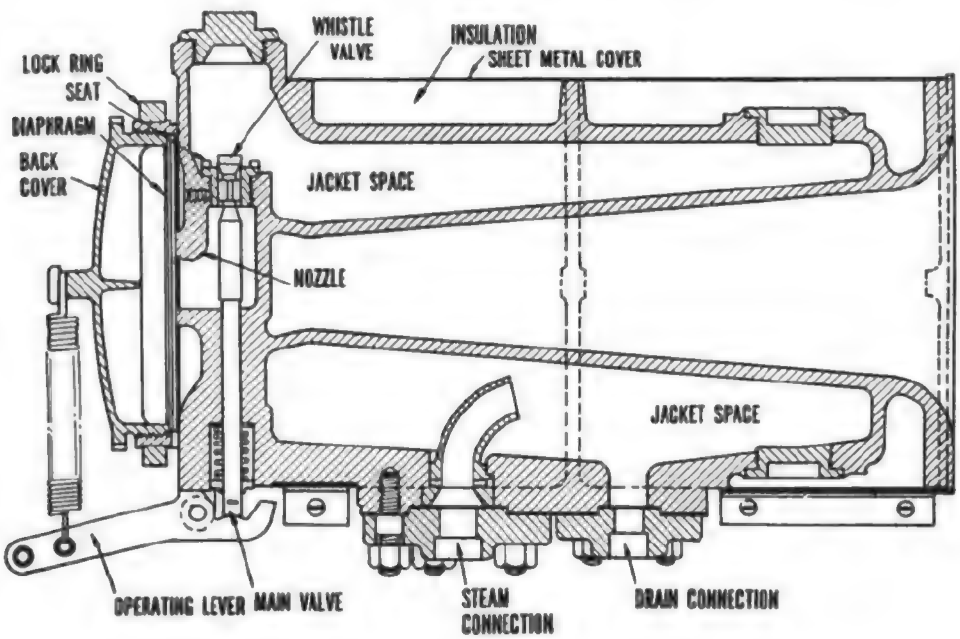
One way to check on the operation of a steam trap is to listen to it. If the trap is leaking, you will probably be able to hear it blowing through the orifice. Another way to check the operation of steam traps is to check the pressure in the drain system. A leaking steam trap causes an unusual increase in pressure in the drain system. When this condition is observed, the defective trap can be located by cutting out traps, one at a time, until the pressure in the drain system returns to normal.

Defective steam traps should be disassembled, cleaned, and inspected. After determining the cause of the trouble, repair or replace parts as required. In some steam traps, the main working parts can be replaced as a unit; in others, you may have to grind in a seating surface, replace a disk, or perform other repairs. Defective trap discharge valves should be reseated. Always install new gaskets when reassembling a steam trap.

STEAM WHISTLES AND SIRENS

Since you will have to maintain, and occasionally repair, the steam whistles and sirens installed on your ship, you should know something about their construction and how they work.

The STEAM WHISTLE illustrated in figure 7-25 is of the diaphragm type, and is typical of the steam whistles used on modern ships. When the operating lever is pulled, the valve opens and admits steam through the orifice. This steam forces the spring-metal diaphragm disks to the left. As the disks attempt to spring back against the nozzle, they vibrate and produce an audible sound. The steam passes out around



47.64X

Figure 7-25.—Sectional view of a diaphragm type steam whistle.

the nozzle and through the horn. Condensate leaks off through the drain connection. Before the whistle is used, the drain should be opened.

To ensure against damage, a steam separator (located below decks) is installed in the steam line to the whistle. The separator removes condensate from the steam by imparting a whirling motion to the steam when it passes on its way to the whistle. The whirling motion is set up by stationary curved baffles and guide vanes. Water is removed from the steam by the centrifugal motion imparted to the steam by the baffles and guide vanes.

Steam enters the STEAM SIREN (fig. 7-26) through a control valve and fills an annular chamber which surrounds a stationary slotted cylinder. This cylinder is pierced by a series of beveled slots. Inside is a second slotted hollow cylinder. The slots of the fixed cylinder act as steam nozzles which direct steam against the rotating cylinder's vertical slots which act as turbine blades. The alternate covering and uncovering of the slots, as the rotor speeds up with pressure of the steam, sets up violent vibrations of increasing frequency in the column of steam escaping through the megaphone above the cylinder. The speed of the inner cylinder rotation determines the pitch of the sound. Brake shoes, attached to the rotating cylinder, prevent overspeeding.

When a ship is in port, the steam lines to the whistle and siren should be secured. About an hour prior to getting underway, the whistle and siren steam lines should be turned on with all drains open and traps in operation for at least 30 minutes to ensure proper heating and removal of condensate. AT NO TIME, while underway, should the whistle and siren steam lines be secured.

PACKING AND GASKET MATERIALS

Packing and gasket materials are required to seal joints in steam, water, gas, air, oil, and other lines and to seal connections which slide or rotate under operating conditions. There are many types and forms of packing and gasket materials available commercially. To simplify the selection of packing and gasket materials commonly used in naval service, the Naval Ship Systems Command has prepared a packing and gasket chart (Mechanical Standard Drawing B-153) showing the symbol numbers and the recommended applications of all types and kinds of packing and gasket materials.

The symbol number used to identify each type of packing and gasket consists of a four-digit number. The first digit indicates the class of service with respect to fixed and moving joints; the numeral 1 indicates a moving joint (moving rods, shafts, valve stems) and the numeral 2 indicates a fixed joint (flanges, bonnets). The second digit indicates the material of which the packing or gasket is primarily composed—asbestos, vegetable fiber, rubber, metal, etc. The third and fourth digits indicate the different styles or forms of the packing or gaskets made from the material.

Practically all shipboard packing and gasket problems can be solved by selecting the correct material from the listings on the packing and gasket chart. The following examples show the kind of information that you can get from the packing and gasket chart.

Suppose you are required to repack and install a valve in a 300-psi saturated steam line. By referring to the packing and gasket chart, you will find several materials that are suitable for repacking the valve:

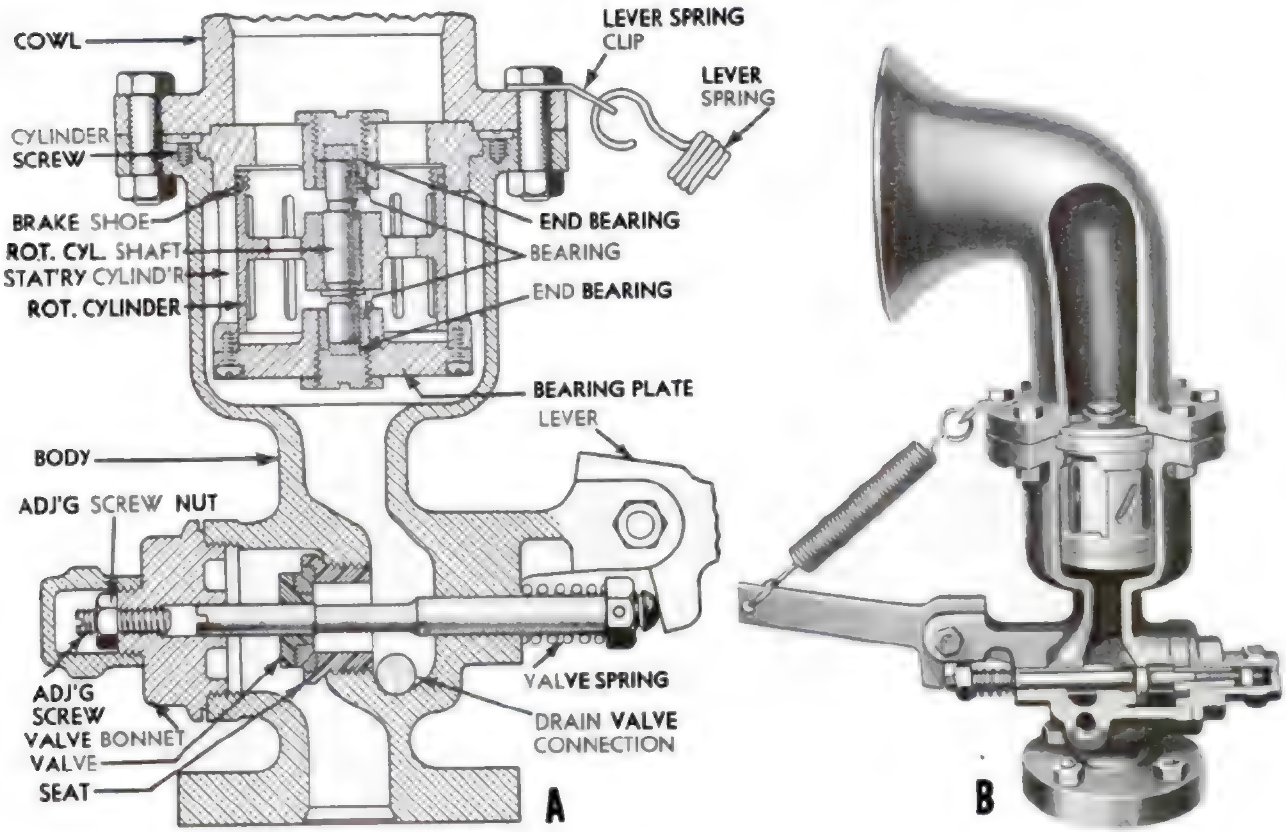
Symbol 1100 . . . . . asbestos, rod, high pressure
Symbol 1103 . . . . . asbestos, rod, braided, plain
Symbol 1400 . . . . . semimetallic asbestos jacket
Symbol 1430 . . . . . metallic, flexible

Notice that the first digit is 1 in each case, to indicate that the packing is suitable for a moving joint.

For installing the valve, you will need suitable gaskets. In this case, the first digit will be 2, indicating that the gasket material is suitable for fixed joints. By referring to the packing and gasket chart, you will find that you can use any of the following materials:

Symbol 2150 . . . . . asbestos, sheet, compressed
Symbol 2151 . . . . . asbestos, metallic cloth, sheet
Symbol 2410 . . . . . gaskets, metallic-asbestos, spiral-wound

In addition to the Naval Ship Systems Command chart, most ships have a packing and gasket chart made up specifically for each ship.



47.65X
Figure 7-26.—Steam siren. A. Sectional view. B. Exterior view.

The shipboard chart shows the symbol numbers and the sizes of packing and gaskets required in the ship's piping system, machinery, and hull fittings.

RENEWING BONNET GASKETS AND SEAL RINGS IN VALVES

Care must be taken in reassembling valves with gaskets under the bonnets to ensure an even compression of the gasket, to prevent misalignment. High pressure steam valves may have been originally furnished with Symbols 2410, 2470 flat, or corrugated soft iron or steel gaskets. Bonnet gaskets should be replaced, when required, with Symbol 2410 gaskets only.

When replacing a pressure-seal ring (gasket) or installing a new valve that has a pressure-seal bonnet, the bonnet joint should be tightened prior to subjecting the valve to line pressure. The joint should be retightened immediately after the valve has been subjected to line pressure and again after two or three days of operation.

If a pressure-seal bonnet joint starts to leak after being in service, retightening of the bonnet studs should stop the leak. If retightening does not stop the leak, the seal ring should be replaced as soon as possible and the installation procedure, mentioned earlier, performed.

PACKING OF MOVING JOINTS

The packing of moving joints offers the most difficulty. The seals must prevent leakage without causing excessive friction, undue wear of the moving part, or rapid deterioration of the packing.

Packing is inserted in STUFFING BOXES that consist of annular chambers located around valve stems, rotating shafts, and reciprocating pump rods. The packing material is compressed

to the necessary extent and held in place by gland nuts or other devices.

The types of packing used for moving joints (illustrated in Fireman, NAVPERS 10524-D) depends primarily on whether the seal is for a sliding or rotating joint. The packing of a SLIDING JOINT may be one of a large variety of types. High pressure asbestos rod packing was formerly used exclusively for sealing steam joints (rods, valve stems, etc.). This type has been superseded to a large extent, however, by WIRE-INSERTED SQUARE-BRAIDED ASBESTOS, (for pressures up to 400 psi and temperatures up to 700° F) and by PLASTIC NON-METALLIC ASBESTOS ENCASED IN A BRAIDED WIRE COVERING (for pressures up to 650 psi and temperatures up to 850° F).

The SEALING OF ROTATING JOINTS is a more difficult problem than that of sliding joints. With this type of joint, it is possible for the packing to create enough friction to prevent the machine from operating. In the sliding joint, the heat of friction created by the packing is dissipated through the moving part of the joint. This does not happen in the rotating joint, where the friction heat builds up on the wearing faces of the packing and the shaft, unless other means are provided for its dissipation. Packings composed of materials with high heat conductivity properties, along with an allowance for leakage, take care of this heat dissipation in rotating joints. It is very important, however, that pressure applied to the packing be kept at the minimum which keeps the leakage within the allowable limits.

In the INSTALLATION OF ROD PACKING, care must be taken both to use the proper packing material and to detect and correct any deficiencies existing in the joint itself. The best grade of packing cannot seal a rod effectively if:

1. The rod is bent, scored, or rusty.
2. The gland is cocked.
3. The stuffing box and gland are scored or nicked.
4. The gland is out of alignment with the shaft.
5. All the old, hard, dry packing is not removed.
6. The threads on the gland studs are burred to the extent that the setting up of the gland nuts is prevented.

Whenever a stuffing box is broken down, the box, gland, rod, and studs should be carefully inspected to determine if any of the above conditions exist. The packing of any moving joint should never be jammed tight with a wrench, as this increases the friction and causes wear of both the packing and the rod.

When installing packing rings in stuffing boxes of moving rods, the ends of the rings should be cut square, not beveled. Enough clearance should be left between the ends of the rings to allow for elongation when the packing is set up. After any possible causes of faulty sealing have been corrected, the cut rings should be installed in the box one at a time with the joints staggered. Insert the gland, draw it up with a wrench, and then back it off until it is finger-tight. A slight leakage will occur during the time the packing is adjusting itself to the rod and box. As the packing expands, further backing off on the nuts may be necessary.

Hydraulic rod packing, such as tuck, and rock hard, must be soaked in water for about 12 hours to allow for swelling, before cutting and fitting in a pump plunger. Step-type joints are best. When it is necessary in an emergency to use this packing dry, be sure to allow enough clearance to provide for the swelling which will occur after the packing has absorbed moisture.

PACKING OF FIXED JOINTS

Fixed steam joints used to be satisfactorily sealed with gaskets of compressed asbestos sheet packing (part A of fig. 7-27), but the 15-percent rubber content of the packing makes it unsatisfactory for modern high temperature steam. Gaskets of corrugated copper or of asbestos and copper are sometimes used on low and medium pressure lines. The following two types of metallic or semi-metallic gaskets are in use in present day high temperature high pressure installations:

1. SERRATED-FACE METAL GASKETS (part B of fig. 7-27), also made of Monel or soft iron, have raised serrations to make a better seal at the piping flange joints. These gaskets have resiliency, and line pressure tends to force the serrated faces tighter against the adjoining flange. The gaskets shown are two variations.

2. SPIRAL-WOUND METALLIC-ASBESTOS GASKETS (part C of fig. 7-27), are composed of interlocked piles of preformed corrugated metal and asbestos strips, spirally wound, called

28.36(47)
Figure 7-27.—Fixed joint gaskets. A. Sheet asbestos gaskets. B. Serrated-face metal gaskets. C. Spiral-wound metallic-asbestos gaskets.

a FILLER and a solid metal outer or centering ring, sometimes called a RETAINING RING. The filler piece is replaceable. When renewal of a gasket is required, this piece should be removed from the retaining metal ring and replaced with a new refill. The solid metal retaining outer ring should not be discarded unless it is damaged. The gasket is then placed into a retainer or centering ring. The solid steel centering ring also acts as reinforcement to prevent blowouts. The gaskets can be compressed to the thickness of this centering ring.

When renewing a gasket in a flanged joint, special precautions must be exercised when breaking the joint, particularly in steam and hot water lines, or in salt water lines which have a possibility of direct connection with the sea. Care should be taken that:

1. There is no pressure on the line.
2. The line pressure valves including the bypass valves, are firmly secured, wired closed, and tagged.
3. The line is completely drained.
4. At least two flange-securing bolts and nuts diametrically opposite remain in place until the others are removed, then slackened to allow breaking of the joint, and removed after the line is clear.

5. Precautions are taken to prevent explosions or fire when breaking joints of flammable liquid lines.

6. Proper ventilation is ensured before joints are broken in closed compartments.

These precautions may prevent serious explosions, personnel scaldings, or compartment floodings. All sealing and bearing surfaces should be thoroughly cleaned for the gasket replacement. The gasket seats should then be checked with a surface plate, and scraped as necessary, to afford uniform contact. All damaged bolt studs and nuts should be replaced. In flanged joints which have raised faces, the edges of gaskets may extend beyond the edge of the raised face.

When cutting a PLAIN FULL-FACED GASKET from compressed asbestos sheet, lay an appropriate size piece of the asbestos sheet on the flange. Scribe in the bolt holes and flange circle lines with light blows of a ball-peen hammer. Using a gasket punch, about 1/16 inch larger in diameter than the bolts, cut the bolt holes into the gasket material. Use a piece of hard wood as the supporting and backing surface for the material while punching it. This will prevent damage to the lips of the punch. After the holes have been punched, use shears or a sharp knife to cut the center and outside circles to form the ring.

PACKING PRECAUTIONS

The following general precautions should be observed with regard to the use of packings:

1. Do not use metallic or semimetallic packing on bronze or brass shafts, rods, plungers, or sleeves. Where this is done, scoring may result. Use a braided packing that is lubricated throughout, or a nonmetallic plastic packing in the center of the box, with an end ring of the braided packing at each end of the box.

2. Do not use a packing frictioned with rubber or synthetic rubber of any kind on rotary or centrifugal shafts. Such packing will overheat.

3. Do not use braid-over-braid packing on rotary or centrifugal shafts. The outer layer will wear through quickly, and eventually the packing will become rags.

4. Do not use packing with a rubber binder on rotary type compressors. It will swell and bind and, thereby, develop excessive frictional heat. The use of flexible metallic packing is recommended, or a lead-base plastic packing alternated with the flexible metallic packing can be used.

5. On hydraulic lifts, rams, and accumulators use a V-type packing or "O" ring. For water, this packing should be frictioned with crude, reclaimed, or synthetic rubber. For oils, the packing should be frictioned with oil-resistant synthetic rubber.

6. Do not use a plastic packing, such as symbol 1433 or 1439, alone on worn equipment or out-of-line rods; it will not hold. A combination of 1433 with end rings of plain braided asbestos (1103), or flexible metallic packing (1430), may be satisfactory for temporary service, until defective parts can be repaired or replaced.

7. Do not use a soft packing against thick or sticky liquids, or against liquids having solid particles. This packing is too soft to hold back such liquids as cold boiler fuel oil, and usually gets torn. Some of the solid particles which may be suspended in these liquids embed themselves in the soft packing, thereafter acting as an abrasive on the rod or shaft. Flexible metallic packing is best for these conditions.

INSULATION

The purpose of insulation is to retard the transfer of heat FROM piping that is hotter than the surrounding atmosphere or TO piping that is cooler than the surrounding atmosphere. The use of insulation helps to maintain the desired temperatures in all systems. In addition, it prevents sweating of piping that carries cool or cold fluids. Insulation also serves to protect personnel from being burned by coming in contact with hot surfaces. Piping insulation represents the composite piping covering which consists of the insulating material, lagging, and fastening. The INSULATING MATERIAL offers resistance to the flow of heat; the LAGGING, usually of painted canvas, is the protective and confining covering placed over the insulating materials; the FASTENING attaches the insulating material to the piping, and to the lagging.

INSULATION TEMPERATURE RANGE

Insulation covers a wide range of temperatures, from the extremely low temperatures of the refrigerating plants, to the very high

temperatures of the ship's boilers. No one material could possibly be used to meet all the conditions with the same efficiency. Cork or rock wool, is used for LOW TEMPERATURES. Such basic minerals as asbestos, carbonate of magnesia, diatomaceous earth, aluminum foil, argillaceous (clay-like) limestone, mica, fibrous glass, and diatomaceous silica are employed for HIGH TEMPERATURES. Because of its high degree of refractoriness, diatomaceous silica forms the base of practically every high temperature insulating material.

INSULATION MATERIALS

The following QUALITY REQUIREMENTS for the various insulating materials are taken into consideration by the Navy in the standardization of these materials:

1. Ability to withstand highest or lowest temperature to which it may be subjected without its insulating value being impaired.
2. Sufficient structural strength to withstand handling during its application, and mechanical shocks and vibrations during service, without disintegration, settling, or deformation.
3. Stability in chemical and insulation characteristics.
4. Ease of application and repair.
5. Must not provide a hazard in case of fire.
6. Low heat capacity, when used for boiler wall and furnace insulation, so that starting-up time may be minimized.
7. Must be moisture repellant and vermin proof.

CORK in sheet form is generally limited to refrigeration spaces. MOLDED CORK PIPE COVERING, treated with a fire-retardant compound, is used on refrigerant piping.

MINERAL OR ROCK WOOL is supplied in wire-reinforced pads. This material is suitable for high temperature use, and is particularly useful for insulating large areas (part A of fig. 7-28).

Molded sheets, pads, blankets, or tapes of long ASBESTOS FIBERS are suitable for insulating temperatures up to 850° F. This insulation material is cheaper and lighter than the diatomaceous earth type, and is durable and rugged. The PADS or BLANKETS are used for insulating flanges or valves which must be taken down fairly often, as well as for turbine casings. The pads are molded to fit any shape, and the outer surface is fitted with metal hooks

47.67X
Figure 7-28. — Piping insulation materials. A. Mineral wool blankets. B. Magnesia-asbestos pipe covering.

to facilitate installation and removal. The blankets are made in various thicknesses and widths, and are also fitted with hooks. TAPES are used for covering small piping with curves and bends. They can be used for temperatures up to 750° F, and tend to reduce fire hazards, but have poor insulating quality.

MAGNESIA-ASBESTOS PIPE COVERING (part B of fig. 7-28) is most commonly used as insulation on high temperature piping. This material is supplied in molded cylindrical sections which are 3 feet long; each section is split in half lengthwise. Suitable widths are available to fit the various pipe sizes. Magnesia-asbestos pipe covering comes in three grades: Grades I, II, and III are suitable for temperatures up to 500° F, 750° F, and 1050° F respectively.

The DIATOMACEOUS EARTH (formed from skeletons of certain microscopic plants) materials are combinations of the earth and magnesium or calcium carbonates, bonded together

with small amounts of asbestos fibers. These materials are heavier, more expensive, and less insulating than others, but their high heat resistance allows their use for temperature up to 1500° F. When practicable, pipe coverings are made up with this material as an inner layer, and with an outer layer of the magnesia-asbestos material. This lightens the overall weight.

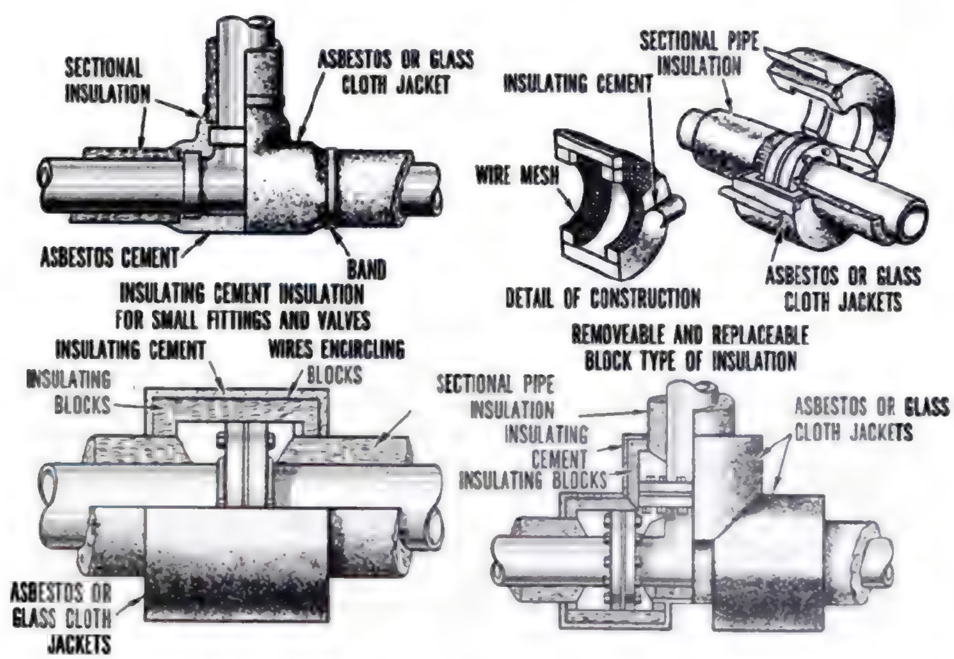
FIBROUS GLASS SLABS AND BATTS are used widely for insulating hull spaces and living quarters. The fibrous glass has a low moisture absorbing quality, and offers no attraction to insects, vermin, fungus growth, or fire. The slabs are first cut to shape, then secured in place by mechanical fasteners (as quilting pins), and covered with glass cloth facing and stripping tape (held in place by fire-resistant adhesive cement).

The INSULATING CEMENTS are composed of many varied materials, differing widely among themselves as to heat conductivity, weight, and other physical characteristics. Typical of these variations are the asbestos cements, diatomaceous cements, and mineral and slag wool cements. These cements are less efficient than other high temperature insulating materials, but they are valuable for patchwork emergency repairs, and for covering small irregular surfaces (valves, flanges, joints, etc.). The cements are also used for a surface finish over block or sheet forms of insulation, to seal joints between the blocks, and to provide a smooth finish over which asbestos or glass cloth lagging may be applied (fig. 7-29).

APPLYING INSULATION

Do not allow the insulating materials to become moist. Moisture impairs the insulating value of the material, and may cause eventual disintegration. Large air pockets in the insulation cause large heat losses, so be sure to fill and seal all cavities or cracks. Hangers or other supports should be insulated so as to prevent loss of heat by conduction.

All sections or segments of the pipe coverings should be TIGHTLY BUTTED AT JOINTS, and secured with wire loops, metal bands, or lacing. Block insulation should be secured with 18 gage steel wire and galvanized mesh wire, or expanded metal lattice. Insulating cement should be used to fill all crevices, to smooth all surfaces, and to coat wire netting before final lagging is applied.



47.68X

Figure 7-29.—Permanent type insulation of pipe fittings, flanges, and valves.

MOISTURE PROOFING is just as important in high temperature insulation as it is in low temperature insulation. In the former case heat is lost because of evaporation, while in the latter case condensed moisture may freeze. In either case, insulating efficiency is impaired and eventually the insulating material disintegrates.

While the same insulating material employed on the piping may be used, the insulation of pipe fittings, flanges, and valves requires additional consideration. Figure 7-29 illustrates several types of insulation for flanged pipe joints adjacent to machinery or equipment that must be broken when units are opened for inspection or overhaul.

REMOVABLE TYPE OF INSULATION is usually installed in the following locations:

1. Manhole covers, inspection openings, turbine casing flanges, drain plugs, strainer cleanouts, and spectacle flanges.
2. Flanged pipe joints adjacent to machinery or equipment that must be broken when units are opened for inspection or overhaul.
3. Valve bonnets of valves larger than 2 inches, IPS, that operate at 300 psi and above, or at 240° F and above.
4. All pressure reducing and pressure regulating valves, pump pressure governors, and strainer bonnets.

For a small unit of machinery or equipment such as an auxiliary turbine, where it would be difficult to install both permanent insulation over the casing and removable and replaceable covers over the casing flanges, the entire insulation may be made removable and replaceable. Covers should fit accurately and should project over adjacent permanent insulation.

For piping components any one of the following methods of fabrication is acceptable:

1. Covers may be made in two halves of thermal insulating felt enclosed in asbestos cloth. Each half cover should be sewn and quilted with wire-inserted asbestos yarn, or fastened with mechanical stapling to provide a uniform thickness, strength, and rigidity.
2. Covers for use at temperatures of 850° F and below, should be filled with asbestos felt. Wire-inserted asbestos cloth should be used on the inside surface of the covers.
3. Covers for use at temperatures above 850° F should have filling consisting of inner layers of fiber-glass felt, outer layers of asbestos felt, and should be covered on the inside surface and on the ends with nickel-chromium alloy wire mesh and on the outside surface with asbestos cloth. Asbestos roll felt, 1/8 inch thick, should be inserted between the asbestos felt and the asbestos cloth to retain the cylindrical shape of the cover.

For removable and replaceable covers for machinery and equipment, either of the following methods of fabrication is acceptable:

1. Covers may be similar to the flexible asbestos felt or fiber-glass type described for piping components.
2. Covers may be made in sections formed of insulating block and held together with wire and adhesive cement, covered with 1/2-inch thickness of finishing cement, and lagged. Lacing with hooks, rings, washers, and wire, or brass snap fasteners should be used to secure the covers.

GENERAL INSULATION PRECAUTIONS

The following general precautions should be observed with regard to the application and maintenance of insulation:

1. Fill and seal all air pockets and cracks. Failure to do this will cause large losses in the effectiveness of the insulation.
2. Seal the ends of the insulation and taper off to a smooth, airtight joint. At joint ends or other points where insulation is liable to damage, use sheet-metal lagging. Flanges and joints should be cuffed with 6-inch lagging.
3. Asbestos cloth covering fitted over insulation should be tight and smooth. It may be sewed with asbestos yarn or may be cemented on.
4. Keep moisture out of all insulation work. Moisture is an enemy of heat insulation fully as much as it is in the case of electrical insulation. Any dampness increases the conductivity of all heat-insulating materials.
5. Insulate all hangers and other supports at their point of contact from the pipe or other unit they are supporting, otherwise a considerable quantity of heat will be lost via conduction through the support.
6. Sheet metal covering should be kept bright and not painted unless the protecting surface

has been damaged or has worn off. The radiation from bright-bodied and light-colored objects is considerably less than from rough and dark-colored objects.

7. Once installed, heat insulation requires careful inspection, upkeep, and repair. Lagging and insulation removed to make repairs should be replaced just as carefully as when originally installed. When replacing insulation, make certain that the replacement material is of the same type as had been used originally. Old magnesia blocks and sections broken in removal, can be mixed with water and reused in the plastic form for temporary repairs. Save all old magnesia for this use.

8. Insulate all flanges with easily removable forms which can be made up as pads of insulating material wired or bound in place, and the whole covered with sheet-metal casings which are in halves, and easily removable.

The main steam, auxiliary steam, auxiliary exhaust, feed water, and steam heating piping systems are lagged to hold in the heat. The circulating drainage, fire, and sanitary piping systems are lagged to prevent condensation of moisture on the outside of the piping.

CHAPTER 8

HEAT EXCHANGERS AND AIR EJECTORS

Any device or apparatus designed to allow the transfer of heat from one fluid (liquid or gas) to another fluid is a heat exchanger. Boilers, distilling plants, and deaerating feed tanks are primary examples of heat exchangers; in common usage, however, these large and relatively complex pieces of equipment are seldom referred to as heat exchangers.

In order for heat to be transferred from one substance to another, a temperature difference is required. Heat flow or heat transfer can occur only from a substance that is at a higher temperature to a substance that is at a lower temperature. When two objects at different temperatures are placed in contact with each other, or near each other, heat will flow from the warmer object to the cooler one until both objects are at the same temperature. Heat transfer occurs at a faster rate when there is a large temperature difference than when there is only a slight temperature difference. As the temperature difference approaches zero, the rate of heat flow also approaches zero.

In some heat exchangers it is desired to RAISE THE TEMPERATURE of one fluid. Fuel oil heaters, combustion air preheaters, lube oil heaters, and many other heat exchangers used on board ship serve this function.

In some heat exchangers we want to LOWER THE TEMPERATURE of one fluid. Lube oil coolers, boiler water sample coolers, and desuperheaters are examples of this type of heat exchanger.

In condensers, we want to REMOVE LATENT HEAT from a fluid in order to make it change from a gas to a liquid. Very often, we want to remove the latent heat without removing any sensible heat—that is, we want to change the state of the fluid but do not want to lower its temperature. For example, the purpose of the main condenser is to remove the latent heat from turbine exhaust steam so that the steam will condense. In this process, however, we do NOT want to lower the temperature of the condensate. Since any heat removed from the condensate must be replaced in the deaerating feed tank or in the boiler, lowering the temperature of the condensate is wasteful of heat and therefore wasteful of fuel.

In some heat exchangers, we want to ADD LATENT HEAT to a fluid in order to make it change from a liquid to a gas. The generating part of a boiler is a good example of this type of heat exchanger. Since it is impossible to raise the temperature of the steam as long as it is in contact with the water from which it is being generated, the steam does not increase in temperature until it has been drawn off into another heat exchanger (the superheater).

This chapter deals with such heat exchangers as you will encounter in the engineroom. These include the main and auxiliary condensers, air ejector condensers, air coolers, lube oil coolers, and deaerating feed tanks.

CLASSIFICATION OF HEAT EXCHANGERS

Heat exchangers may be classified according to the path of heat flow, the relative direction of the flow of the fluids, the number of times that either fluid passes the other fluid, and the general construction features such as the type of surface and the arrangement of component parts. The types of heat exchangers in common use on naval ships are described in the following sections in terms of these basic methods of classification.

PATH OF HEAT FLOW

When classified according to the path of heat flow, heat exchangers are of two basic types. In the INDIRECT or SURFACE type of heat exchanger, the heat flows from one fluid to the other through some kind of tube, plate, or other

"surface" that separates the two fluids; consequently, there is no mixing of the fluids. In the DIRECT CONTACT type of heat exchanger, the heat is transferred directly from one fluid to another as the two fluids mix. The deaerating feed tank is a direct contact heat exchanger; practically all other heat exchangers used on board ship are of the indirect or surface type.

DIRECTION OF FLUID FLOW

In surface heat exchangers, the fluids may flow parallel to each other, counter to each other, or at right angles to each other (crossflow).

In PARALLEL FLOW, both fluids flow in the same direction. If a parallel flow heat exchanger has a long enough heat transfer surface, the temperatures of the two fluids will be practically equal as the fluids leave the heat exchanger.

In COUNTERFLOW, the two fluids flow in opposite directions. Counterflow heat exchangers are used in many applications where it is necessary to obtain a large temperature change in the cooled or heated fluid.

In CROSSFLOW, one fluid flows at right angles to the other. Crossflow is particularly useful for removing latent heat and thus condensing a vapor to a liquid.

Counterflow and crossflow heat exchangers are more commonly used than the parallel flow type on board ship. Fuel oil heaters, lube oil coolers, and many internal combustion engine coolers are examples of the counterflow type. Crossflow is used for most condensers, including the main and auxiliary condensers. In many heat exchangers, the types of flow are combined in various ways so that is is not always easy to determine whether the flow is basically parallel, counter, or cross.

NUMBER OF PASSES

Surface heat exchangers may be classified as SINGLE-PASS units if one fluid passes another only once; or as MULTIPASS units, if one fluid passes another more than once. Multipass flow may be obtained either by the arrangement of the tubes and of the fluid inlets and outlets, or by using baffles to guide a fluid so that it passes the other fluid more than once before it leaves the heat exchanger.

TYPE OF SURFACE

Surface heat exchangers are known as PLAIN SURFACE units, if the surface is relatively smooth, or as EXTENDED SURFACE units, if the surface is fitted with rings, fins, studs or some other kind of extension. The main advantage of the extended surface lies in the fact that the extensions increase the heat transfer area without requiring any substantial increase in the overall size and weight of the unit.

TYPE OF CONSTRUCTION

Surface heat exchangers are often called by names that indicate general features of design and construction. Basically, all surface heat exchangers are of SHELL-AND-TUBE construction. However, the shell-and-tube arrangement is modified in various ways and in some cases it is not easy to recognize the basic design. Shell-and-tube heat exchangers include such types as (1) straight tube, (20 U-tube, (3) helical or spiral tube, (4) double-tube, (5) strut tube, and (6) plate tube heat exchangers.

In STRAIGHT TUBE heat exchangers, the tubes are usually arranged in a bundle and enclosed in a cylindrical shell. The ends of the tubes may be expanded into a tube sheet at each end of the bundle or they may be expanded into one tube sheet and packed and ferruled into the other. The use of ferrules allows the tube to expand and contract slightly with temperature changes.

U-BEND heat exchangers, sometimes called RETURN BEND heat exchangers, consist of a bundle of U-shaped tubes inside a shell. Since the tubes are U-shaped, there is only one tube sheet. The shape of the tubes provides a sufficient allowance for expansion and contraction.

HELICAL TUBE or SPIRAL TUBE heat exchangers have one or more coils of tubing installed inside a shell. The tubes may communicate with headers at each end of the shell; or in the case of relatively simple units such as boiler water sample coolers the ends of the tubing may pass through the shell and serve as the inlet and the outlet for the fluid that flows through the coil of tubing.

DOUBLE-TUBE heat exchangers have one tube inside another. One fluid flows through the inner tube and the other flows between the outer and the inner tube. The outer tube may thus be regarded as the shell for each inner tube. The

shells or outer tubes are usually arranged in banks and are connected at one end by a common tube sheet and a partitioned cover that serves to direct the flow. Many double-tube heat exchangers are of U-bend construction to allow for expansion and contraction. The sectional G-fin fuel oil heater commonly used in the Navy is an example of a double-tube heat exchanger.

STRUT TUBE and PLATE TUBE heat exchangers are noticeably different in design from the other shell-and-tube heat exchangers. The tubes in both strut tube and plate tube heat exchangers consist of pairs of flat, oblong strips; one fluid flows inside the tubes and the other flows around the outside. Strut tube and plate tube heat exchangers are used primarily as water coolers and lubricating oil coolers in internal combustion engines; they are also used as lube oil coolers for some small auxiliary turbines.

STEAM CONDENSERS

A condenser is a type of heat exchanger used to remove latent heat from a vapor and thereby change the vapor to a liquid. Since the main condenser of a steam plant is one of the most important units in the plant, the operation of the main condenser is discussed here in some detail.

MAIN CONDENSERS

A typical main condenser system is illustrated in figure 8-1. There are two separate circuits involved in the condensation of steam in a condenser of this type. The first is the vapor-condensate circuit, in which exhaust steam from the propulsion turbines is condensed as it comes in contact with tubes through which cool sea water is flowing. The condensate then falls to the bottom of the condenser, drains into a space called the HOT WELL, and is removed by the condensate pump. The main condenser is the heat receiver of the thermodynamic cycle—that is, it is the low temperature heat sink to which some heat must be rejected. The main condenser is also the means by which feed water is recovered and returned to the feed system. If we imagine a shipboard propulsion plant in which there is no main condenser and the turbines exhaust to atmosphere, and if we consider the vast quantities of fresh water that would be required to support even one boiler generating 150,000 pounds of steam per hour, it is immediately apparent that the main condenser serves a vital function in recovering feed water. Air and other non-condensable gases which enter with the exhaust steam are drawn off by the air ejector through an AIR EJECTOR SUCTION OPENING in the shell, above the condensate level. The second circuit in the condenser is the cooling water circuit. During normal ahead operation, sea water

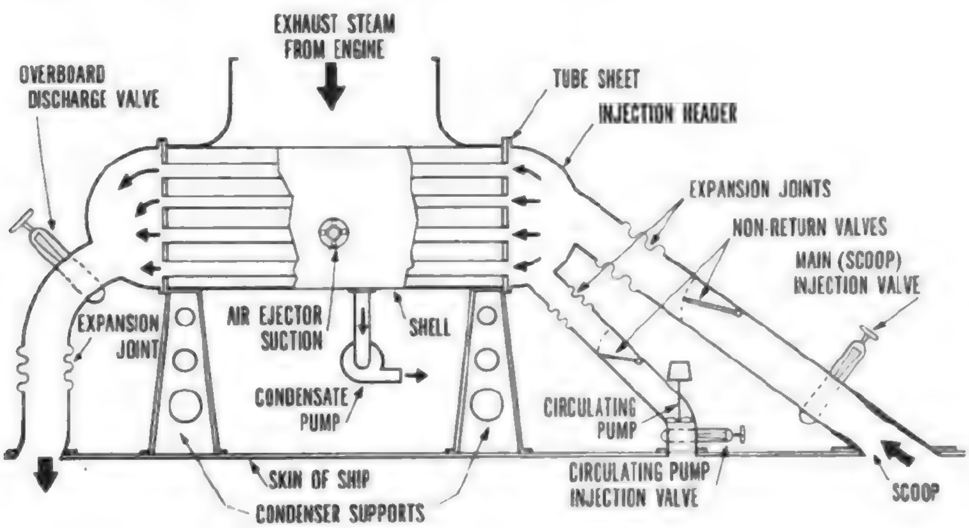


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Figure 8-1.—Schematic arrangement of a main condensing system.

flow through the condenser is provided automatically by means of the INJECTION SCOOP. The scoop, located below the waterline, and the forward motion of the ship (5 knots or above) causes sea water to flow through the condenser. A major advantage of scoop injection is that it provides a flow of cooling water at a rate which is controlled by the speed of the ship and hence is automatically correct for various conditions. Scoop injection is standard for naval combatant ships and for many of the modern auxiliary ships. STRAINER BARS are installed in the sea chest to strain out debris which could foul the piping and the condenser tubes. The injection and overboard discharge lines are provided with expansion joints to prevent undue strains as a result of either change in temperature or working of the hull.

A main CIRCULATING PUMP provides a flow of water through the condenser at times when scoop injection is inadequate—as, for example, when a ship is stopped, backing down, or moving ahead at a very slow speed. A large SWING-CHECK VALVE or NONRETURN VALVE which prevents backflow of water is installed in the main injection line; another one is installed in the main circulating pump discharge line. When water is flowing into the condenser through the main injection line, the nonreturn valve in the main circulating pump discharge line prevents the backflow of water through the pump. When the circulating pump is in operation, the nonreturn valve in the main injection line prevents backflow of water through that line.

In all cases, the main circulating pump must have a large capacity (as high as 40,000 gpm against a very low head). The pump is usually of the propeller type. The main circulating pump is provided with a bilge suction line so that it can be used to pump water overboard in case of serious flooding of the engineroom.

Construction

To ensure proper maintenance of a condenser, there are certain installation and construction features which you should understand. Modern installation practice is to suspend the condenser from the turbine rather than to have the condenser support the turbine. This allows for a greatly reduced weight and makes it unnecessary to use an expansion joint between the turbine and the condenser.

All main condensers that have scoop injection are of the straight-tube, single-pass type; they are usually of the general construction shown in figure 8-2.

A main condenser may contain from 2000 to 10,000 copper-nickel alloy tubes, usually of 5/8-inch diameter. The length of the tubes and the number of tubes depend upon the size of the condenser; and this, in turn, depends upon the capacity requirements. The tube ends are usually expanded into the tube sheet at the inlet end and are flared after expansion. The outlet tube ends are either expanded or else packed or ferruled into the tube sheet. Condensers having tubes ferruled into each tube sheet are found in some older ships.

The tube sheets serve as partitions between the salt water circuit and the vapor-condensate circuit. Access to the tube sheets is by way of manholes in each water chest.

Various methods of construction are used to provide for relative expansion and contraction of the shell and tubes in main condensers. Packing the tubes at the outlet end is sometimes sufficient. Where the tubes are expanded into each tube sheet, the shell may have an expansion joint. In some condensers the tubes are arranged to bow upward about one-half inch at the middle; this provides for expansion and contraction and also makes it easier to drain the salt water side of the condenser. Expansion joints are also provided in the scope injection line and in the overboard discharge lines as shown in figure 8-1. In recent installations, additional means such as a flexible support foot or lubricated sliding feet are provided to compensate for expansion and contraction differentials between the shell and the condenser supporting structure.

As the steam is condensed on the tubes, the condensate drips down and collects on a receiving tray. Because of the arrangements made for steam flow in a main condenser, some steam flows under the tube bundle and thereby reheats the condensate. From the receiving tray, the condensate drains to the hot well, where the condensate pump takes suction.

Main condensers have various internal baffle arrangements for the purpose of separating air and steam so that the air ejectors will not be overloaded by having to pump large quantities of steam with the air. One arrangement that provides separate air-cooling sections is shown in figure 8-2. The air baffles are extended up the side of the condenser shell. Figure 8-3 illustrates a cross-sectional view of a typical condenser.

Information on specific construction features of main condensers is available in the manufacturer's technical manual for the condenser concerned.

Operation

Under conditions of warming up, standing by, getting underway, cooling down, and securing the main engines, the condenser vacuum should be regulated in accordance with information given in engineering operating procedures and any orders issued by the engineer officer.

Two basic rules that apply to the operation of single-pass main condensers should be kept in mind. The first is that the OVERBOARD TEMPERATURE should be about 10° higher than the INJECTION TEMPERATURE. The second rule is that the condensate discharge temperature should be within 0° to 2° F of the temperature corresponding to the vacuum in the condenser. The accompanying chart lists vacuums (based on a 20.00-inch barometer) and corresponding temperatures.

Inches of Mercury	Corresponding Temperature (°F)
29.6	53
29.4	64
29.2	72
29.0	79
28.8	85
28.6	90
28.4	94
28.2	98
28.0	101
27.8	104
27.6	107

Scoop injection systems are designed to provide a sufficient amount of cooling water at speeds of 5 knots and above, with the injection and overboard valves wide open. Ordinarily it is not necessary to control the circulating water flow by throttling the valves. If throttling becomes necessary because the ship is in cold waters or because of other unusual operating conditions, the proper valve to use is the overboard valve; the valve should never be more than three-fourths closed. Using the inlet valve to throttle the flow of circulating water would cause turbulence and consequent erosion of the tubes.

If the condenser vacuum is not as high as it should be in relation to the condenser load and the cooling water overboard temperature, some part of the condensing system is not functioning properly. You may find, for example, that the air ejectors are not properly removing air from the condenser, that the condensate pump is not keeping the right condensate level, or that there is an air leak in the condenser or in some other part of the system under vacuum.

The condensate level should be kept as low as possible while maintaining a continuous flow of condensate through the air ejector. It should not rise into the condenser shell. Allowing the level to rise slightly higher than the top of the hot well causes the condensate temperature to be lower than normal because the path for the flow of reheating steam is partially blocked by the condensate. (Reheating steam is the steam which enters the hot well by way of the central steam lane. The central steam lane extends completely through the tube bundle and provides for longitudinal distribution of steam from the exhaust inlet directly to the condenser hot well.) If the condensate level is allowed to rise to the bottom row of tubes, the flow of reheating steam is further restricted, causing an even greater drop in condensate temperature. At this point, the high condensate level begins interfering with the flow of air toward the air removal areas, thus causing a gradual loss of vacuum. A rapid loss of vacuum, accompanied by a rapid increase in condenser shell temperature and exhaust trunk temperature, results if the condensate level rises to the lower end of the air baffles. This results not only because air removal ceases but also because a large part of the tube bundle is submerged and not available for cooling and condensing the incoming steam. If the condensate level rises and cannot be brought down to normal immediately by speeding up the condensate pump or by cutting in an additional pump, the speed of the main engine must be reduced to avoid serious damage to the turbine and condenser.

An adequate flow of circulating water must be provided continuously to an operating condenser. This circulating water cools the steam and causes it to condense. Failure of the circulating water supply causes overheating of the condenser and loss of vacuum. Unless the situation is corrected immediately, steam pressure will build up to the point where it might cause the condenser shell to rupture.

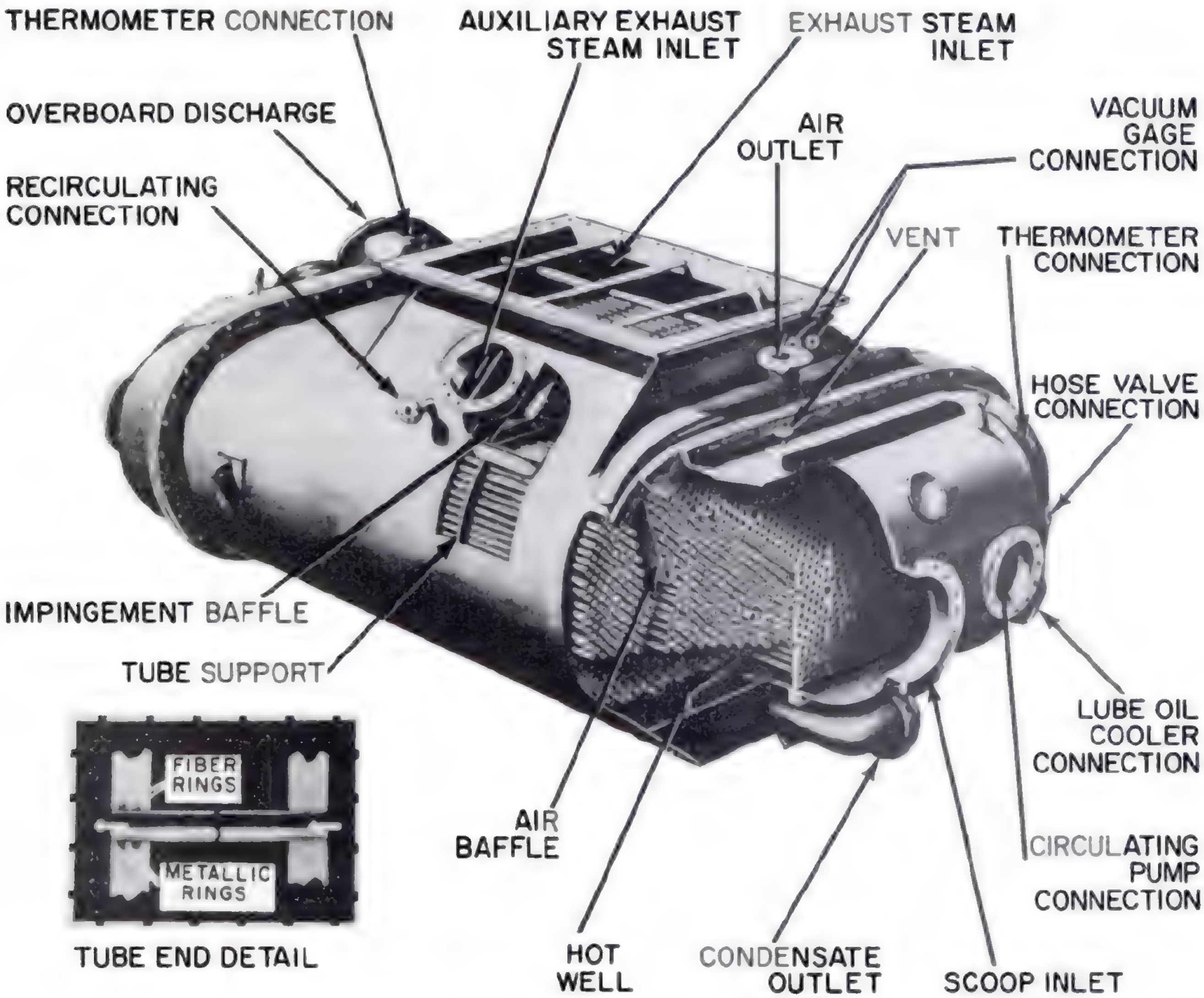

Figure 8-2.—Cutaway view of a main condenser.

Causes of insufficient circulating water are:

1. Condenser tubes clogged with foreign matter such as fish, seaweed, or mud.
2. Obstruction of injection or discharge sea chests, piping, or valves.
3. Injection or overboard valves not properly adjusted.
4. Inefficient or inoperative circulating pump.
5. Obstructed air vents (condenser vapor bound).
6. Faulty nonreturn valves (flappers) in scoop injection lines or in main circulating pump discharge lines.

Steam or air connections are provided to clear foreign matter from sea chests. Sometimes, however, thick accumulations of marine growth on or around sea valve openings cannot be blown clear. When maximum pressure fails to clear a sea chest, the obstruction must be removed by a diver.

Air vents must be kept open under all operating conditions where air is vented overboard through the hull or where the inlet water chest is vented to the discharge water chest or piping, to minimize air erosion of the tubes and to avoid air-binding. Vents that are piped to the bilges should be kept slightly open at all times when the condenser is in use. As long as a trickle of water escapes, the unit will not become air bound and the circulating water flow will not be obstructed.

Main condenser circulating pumps are provided with a bilge suction which has the largest

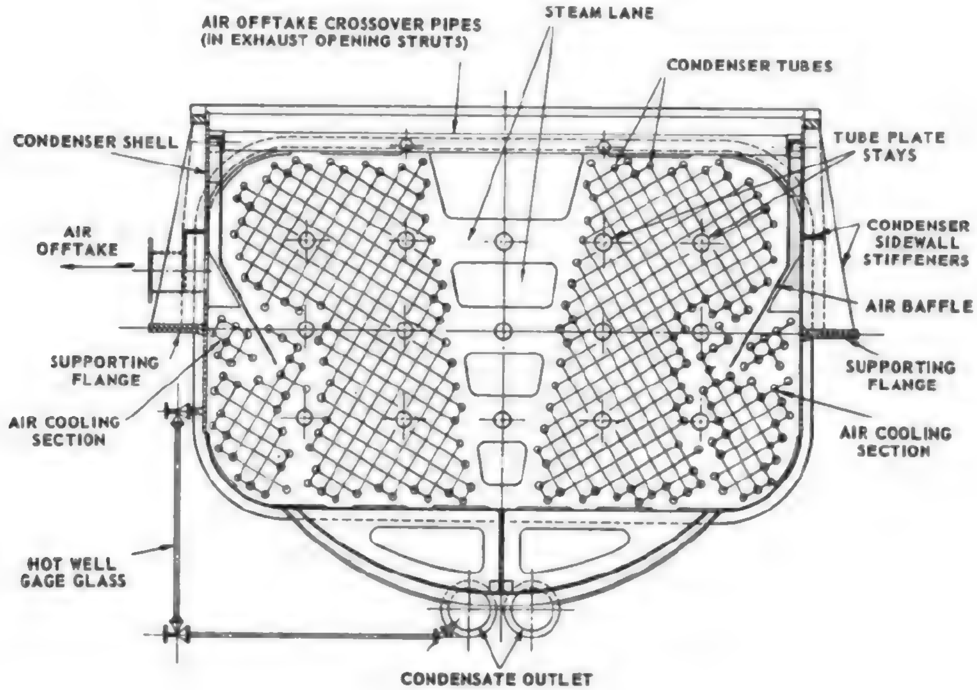

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Figure 8-3.—Cross-sectional view of a main condenser.

potential capacity available for pumping engine-room bilges.

If a main circulating pump operates on bilge suction, it should be started the same as for main condenser circulating service, then the main injection valve should be gradually closed and the bilge suction valve opened. When the pump is operating on a high suction lift (as when pumping bilges), the speed should be reduced to approximately 2/3 of rated speed. Pump noise can be minimized by slowing the pump.

AUXILIARY CONDENSERS

Condensers into which turbogenerators exhaust are generally referred to as auxiliary condensers. They operate on the same principle as main condensers. In an auxiliary condenser, however, the cooling water is pumped through the condenser at all times instead of being scoop injected. Also, most auxiliary condensers are of two-pass rather than single-pass construction. Figure 8-4 shows a two-pass auxiliary condenser; the sea water chest is divided into an inlet chamber and a discharge chamber. In other construction features, including the metals used, auxiliary condensers are similar to main condensers.

Auxiliary exhaust steam, beyond that required for units such as the deaerating feed tank and the distilling plants, may be directed either to the the auxiliary condenser or to the main condenser. In port, the auxiliary exhaust goes only to the auxiliary condenser. When getting underway, the exhaust goes to the auxiliary condenser until vacuum in the main condenser is sufficiently high.

MAINTENANCE OF STEAM CONDENSERS

Heat exchangers and associated equipment should be periodically tested and inspected to ensure that they are operating efficiently. Preventive maintenance is much more economical than corrective maintenance. All preventive maintenance should be conducted in accordance with the 3-M System.

Air Leaks

The desired condenser vacuum cannot be maintained if the condenser leaks. Leaks at

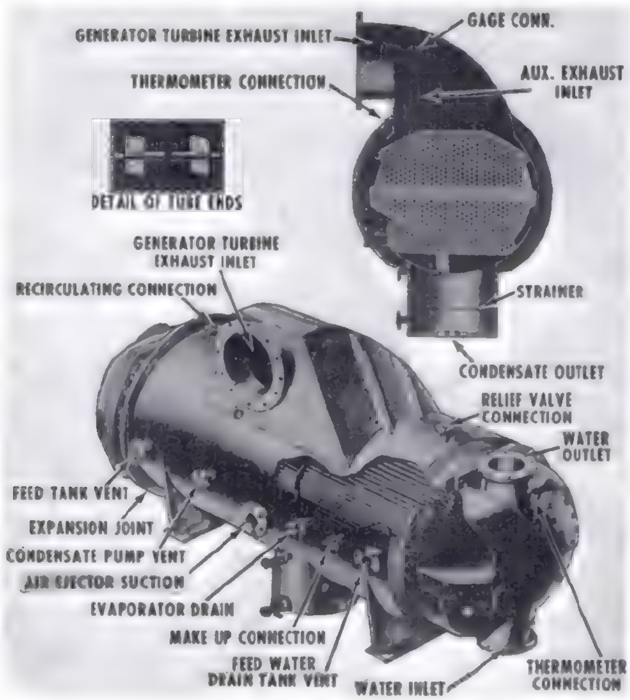

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Figure 8-4. —Auxiliary condenser (turbo-generator).

flanged joints and through porous castings can usually be stopped temporarily with an application of shellac when the condenser is under vacuum. Leaks around valve stems can sometimes be eliminated by tightening the packing. Small leaks around porous castings, flange nuts, valve stems, etc., can sometimes (but not always) be located by the candle test. Hold a lighted candle close to areas where leaks are suspected and see if the flame flickers. A more reliable means of locating condenser air leaks is by use of soapsuds while the steam side of the condenser is under pressure. Remove one of the thermometer wells and install a pressure gage and line. Now subject the steam side of the condenser to a pressure not exceeding 15 psig. Apply soapsuds to the units and areas where a leak is suspected and watch for the formation of bubbles.

All places where it is possible for an air leak to exist should be investigated. Some of the places to look for possible leaks include the following:

1. Makeup feed line
2. All gage lines
3. Drain collecting system drain line
4. Air ejector inter condenser drain line
5. Condensate pump suction line, vent line, and gland sealing system
6. Condensate and vent lines under vacuum
7. Air-removal suction line
8. Thermometer connections
9. Main exhaust flange and turbine exhaust trunk manholes
10. Fittings with porous castings
11. Shell relief valve
12. Evaporator drain line
13. Boiling-out connection at bottom of shell
14. Drain connections or plates at bottom of hot well
15. Hot well gage glass and fittings
16. Auxiliary exhaust dumping line
17. Turbine drain lines
18. Condensate recirculating line

Cleaning Condensers

Foreign matter lodged on the steam side of the condenser tubes interferes with and reduces the rate of the flow of heat from the condensing steam to the circulating water. This, in turn, reduces the maximum vacuum obtainable and lowers the efficiency of the condenser. The lodgment of foreign matter on the sea water side of the tubes is detrimental to the tubes themselves in addition to slowing down the transfer of heat. Frequent visual inspections provide the only safe means of knowing the conditions of condenser fouling.

Grease and dirt on the steam side of a condenser may be boiled out with a solution of trisodium phosphate. Normally, though, this boiling-out process should not be necessary more than once every 2 or 3 years. (Condensers serving engines may require boiling out operations much more frequently.)

To boil out a condenser, proceed as follows:

1. Drain and clean the sea water side.
2. Close condensate or air pump suction and other valves in the lines connected to the condenser.
3. For each 1,000 gallons of water the steam side of the condenser will hold, make a mixture of 200 gallons of fresh water with 110 pounds

of trisodium phosphate anhydrous and 5 quarts of wetting agent. Dissolve the compound thoroughly in hot water and introduce the mixture into the condenser shell.

4. Fill the steam side of the condenser with fresh water to above the top row of tubes unless the water at this height, when brought to the boiling temperature, will enter the turbine exhaust trunk. In such cases the height should be regulated.

5. Introduce live steam into the condenser through the boiling out connection and bring the contents to the boiling point at atmospheric pressure. Care must be taken that the condenser is vented to the atmosphere during this operation and that no pressure is allowed to build up within the condenser shell.

6. Boil out the condenser for about 12 hours at the temperature, or boiling point, mentioned in the previous step.

7. Dispose of the spent solution in accordance with local regulations. Care must be taken that none of the emulsion is admitted to the feed system.

8. Before the condenser has had time to dry, wash out the condenser several times with fresh water, follow by removing an inspection plate near the bottom of the condenser, and hose out all sediment collected in the bottom of the hot well.

9. Test the condenser for leaks.

10. Before and during this boiling out of a condenser, inspection shall be made, by the division officer and the petty officer in charge of the station, of all boiling out and drainage arrangements to provide against accidents, and proper safeguards should be provided for the men engaged in this work.

The SEA WATER SIDE of the tubes should be cleaned as often as necessary; the intervals depending upon the rate at which slime, marine growth, scale, mud, oil, grease, etc., are deposited on the tube walls. The amount of such deposits depends upon existing conditions. Operation in shallow water, for example, may cause this fouling of the tubes. For ordinary cleaning, the tubes can be scrubbed out with a rotating bristle brush, or an air lance may be pushed through them. Another method is to shoot soft rubber plugs (fig. 8-5) through the tubes by means of compressed air or water under pressure.

47.73

Figure 8-5.—Types of rubber plugs used for cleaning condenser tubes.

Care of Idle Condensers

The salt water side of the idle condenser should be kept dry. If the condenser is to be put into active use again in a few days, it may be kept filled and the water should be circulated daily. One exception should be noted: when the ship is anchored in highly polluted waters, the sea water side should be drained and thoroughly washed out whenever the condenser is secured. The steam side of the condenser should always be dry when the condenser is secured.

Whenever the sea water side of a condenser is drained, special care should be taken to ensure that the tubes do not have water anywhere along their lengths. Tubes frequently become sagged and water trapped in these pockets at one or more points along the tube length, if allowed to remain in a drained condenser, will gradually evaporate. The impurities left behind (after the water has evaporated) will corrode the tubes at these points, and in time result in failure. This action is particularly acute when condensers are drained of highly polluted water, generally in harbors. The best method of avoiding this type of tube deterioration, when an ample supply of fresh water is available from a pier, is to water-lance each tube with fresh water in order to wash out the polluted water and remove foreign matter from the tubes. Following the water-lancing operation, the tubes should be air-lanced and left dry until the condenser is again put to service. If the tubes cannot be left completely dry, the sea water side should be left completely filled with fresh water following the cleaning operation.

If sufficient fresh water is not available for water-lancing, each condenser tube should be air-lanced and left completely dry; then the condenser should be inspected daily. If any water

tends to collect in the tubes, through condensation from the atmosphere, the air-lancing operation should be repeated, as necessary, to avoid the formation of water pockets at low points along the tubes.

To avoid possible damage to an idle condenser and the associated turbine, see that the valves admitting steam to the condenser, such as the auxiliary exhaust dumping valve are closed.

Salt Water Leaks

Leakage of sea water into the condensate through even one tube, out of the thousands installed will contaminate the feed water. Sea water leakage into the system is serious; the entire feed system will salt up and the ship's boilers will become badly damaged as a result.

You may learn that a leak exists by watching the salinity indicator (described in chapter 14 of this training manual). The indicator, usually located at a position convenient to the main control station in the engineroom, must be kept in operative condition at all times. Salinity cells must be checked frequently. When the salinity reading goes above normal, action should be taken as soon as practicable to determine the cause.

Objectionable salt water leakage cannot always be detected by the conductivity type salinity indicators installed in the condensate system, because of the large quantity of condensate which generally flows. The first indications of sea water leakage in the active tube length between the tube sheets may be a chloride buildup in the boiler or the steam generator (of newly constructed plants) or, when the plant has been secured, in the hotwell of the idle condenser.

Care must be taken to ensure that the source of chloride contamination is not in the piping connected to the condenser rather than in the condenser tubes. Special attention should be given to these sections of the condensate, drain, or makeup feed piping, normally under vacuum and located in the bilge area. Experience has demonstrated that leakage of bilge water into joints of this piping may occur, and may not be detected until after considerable time and effort have been devoted to a search for a tube leak. Therefore, when a search is instituted for the source of salt water contamination of the condensate, all such piping should be uncovered by lowering the level of water in the bilges, and all joints should be inspected while the condenser and the piping are filled with fresh water under pressure as described in the paragraphs which follow.

Several test methods designed to locate the source of circulating water leakage into condensers or other heat exchangers are described in the sections which follow.

The method selected will depend upon the design of the condenser or heat exchanger in question, accessibility of its various parts, and availability of the test equipment required. In general, the simplest suitable test should be used first.

Prior to starting any test work, review the "PRECAUTIONS TO BE OBSERVED WHEN TESTING OR CLEANING CONDENSERS." The recommended methods, approved by the Naval Ship Systems Command, used to detect tube leakage, are discussed in the paragraphs which follow.

THE PROCEDURE FOR USING METHOD I IS AS FOLLOWS:

1. Drain the sea water side of the condenser and remove the waterbox inspection plates.
2. Ventilate the sea water side of the condenser.
3. Wash clean the waterbox, tubes, and tube sheets, and dry the tubes and tube sheets by using compressed air.
4. Fill the steam side of the condenser with fresh water of feed water quality, being careful not to flood the low pressure turbine.
5. Inspect the tube ends, since at this point a gross leak may be detected. It is advisable, however, to apply an air pressure, not exceeding 15 psi over the water to ensure that all leaks are located.
6. The sensitivity of this test will be increased by careful drying of the tubes and the tube sheets, and by using warm water to fill the condenser to prevent condensation on the tube sheets and in the tube ends.
7. Additional sensitivity may be obtained by adding an appropriate sea marker dye to the condenser at the rate of 3.0 ounces per 1,000 gallons of water. The dye should be premixed with fresh water to ensure thorough mixing. The tube ends on the circulating water side of the condenser are then inspected by using an ultra violet lamp, or an ordinary flashlight, if an ultra violet light is not available.

CAUTION: Sea marker dye contains chlorides. Care should be taken to see that the steam side of the condenser is carefully flushed so that these chlorides do not enter the boiler via the condensate system. In condensers of nuclear power plants, it is preferable to use sodium fluorescein to preclude any possibility of chlorides contaminating the feed system.

If faulty tubes are found, they should be plugged at each end with the tube plugs furnished to the ship. Plugs should be driven firmly into the ends with light hammer blows. If it becomes necessary to plug tube sheet holes after a tube has been removed, it is good practice to install short sections of a capped tube in the tube holes and secure them by expanding prior to inserting tube plugs; this will protect the tube holes from damage. Plugged tubes should be renewed, if possible, at a naval shipyard during the next availability for the ship.

THE PROCEDURE FOR USING METHOD II IS AS FOLLOWS:

1. Drain the condenser circulating water side, and remove the water box inspection plates.
2. Place the steam side of the condenser under air pressure not exceeding 15 psi.
3. Slowly fill the circulating water side of the condenser with water. Replace the lower inspection plates, as the water level nears the openings.
4. Carefully watch the surface of the water adjacent to both tube sheets for air bubbles that will indicate leakage.
5. Gross leakage should be immediately noticeable. Smaller leakage, especially in a tube requires time and close observation to ensure detection. Note the trim or list of the ship and maintain a close watch of the high end of the tubes. If the drawing of the condenser or heat exchanger indicates that the tubes are bowed, this fact should be considered when inspecting for leakage.

THE PROCEDURE FOR USING METHOD II-A IS AS FOLLOWS:

1. It is often found that there are tubes located above the lower edge of the highest waterbox inspection opening and Method II cannot be used to find a leaking tube in this location. It will be advantageous to install plexiglass or other transparent plates, of 3/8 inch or greater thickness, on the upper inspection openings. The plastic plates should be cut to the outside dimensions of the inspection opening flanges and have steel backup flanges conforming to the outside and inside dimensions of the flanges. Soft rubber gaskets should be used.
2. Method II should be followed until the water reaches the lower edge of the upper inspection opening; the plastic plates and backup flanges should be installed, and the circulating water side filled with water. (Fresh water will probably be necessary in harbor areas for good visibility.)
3. If desirable, plastic plates may be installed on all inspection openings instead of only the upper ones; the circulating water side may be filled with water, and the tube ends observed for air bubbles.

THE PROCEDURE FOR USING METHOD III IS AS FOLLOWS:

1. Drain the circulating water side of the condenser, and remove the water box inspection plates.
2. Ventilate the circulating water side of the condenser.
3. Wash clean the waterbox, tubes, and tube sheets, and dry the tubes and tube sheets by using compressed air.
4. Apply a light coat of grease to each tube sheet face. Place pieces of light sheet plastic such as "Saran Wrap" against each tube sheet. Seal the plastic sheet by pressing the material around the tube holes.
5. Using the air ejector equipment associated with the condenser or other available means, obtain the maximum vacuum possible in the steam side of the condenser. For precautions to be observed during this step of the test, consult the applicable technical manual for the equipment served by the condenser.
6. Carefully observe the appearance of the plastic sheet sealing the ends of each tube. A tube leak will be indicated by a star-like puckering or possibly complete failure of the plastic at the ends of defective tube.
7. If the leak is not detected within the first 30 minutes after a vacuum is obtained in the condenser, a different test method should be used. Continuation of this test for an extended period will usually result in false indications of leakage caused by air pressure changes in the ship.
8. Use extreme care in removing the plastic sheet from the tube sheets. Using a hot water hose, remove as much grease as possible from the tube ends and tube sheets.

METHOD IV is the suggested method to use to detect minute leaks in the condenser which cannot be detected by simpler means. This method is particularly applicable to condensers of recently constructed plants in which chloride contamination of the steam generator cannot be tolerated; therefore, extraordinary means must be taken to eliminate salt water leaks. This

method requires much time, labor, and special equipment (a limited amount of which is available upon application to the Naval Ship Systems Command, and certain equipment may be available at naval shipyards and other repair facilities).

Method IV consists of two distinct tests known as Test A and Test B, designed respectively to determine whether the condenser is leaking and, if so, the location of the leak.

The object of Test A is to determine the tightness of the condenser and, depending upon the access available, to inspect the steam side of the condenser to acquire knowledge as to the general location of the leak. This test consists of pressurizing the sea water side of the condenser using fluorescent dye and water mixture while inspecting the steam side of the condenser, using ultra violet light. During this test, the waterbox flanges and the piping in the bilge will also be inspected by using ultra violet light.

The object of Test B is to locate a leaky tube. It consists of pressurizing internally a group of tubes and monitoring the pressure drop in each tube, using nitrogen gas at 500 psig.

Four possible sources of salt water leakage into the condenser are as follows:

1. At a tube end, due to leakage between the external tube wall and the tube sheet, or through the tube packing. This can be discounted in the case of double tube sheet condensers such as are used in condensers in newly constructed ships.

2. Through a small hole in a tube.

3. Via a path under a water box tube sheet-flange gasket, the clearance holes in the flange bolting, and under the tube sheet-shell flange gasket into the condenser shell. In double tube-sheet condensers in which the inner steel-tube sheet is welded to the shell, thus eliminating the gasketed joint, this possibility is eliminated.

4. In the piping, or joints thereof, connected to the condenser and normally under vacuum, and which are sometimes submerged in the bilge.

METHOD V is used for detecting salt water leaks in double tube sheet condensers where joint leakage occurs in the tube to the outer tube sheet. THE PROCEDURE FOR USING METHOD V IS AS FOLLOWS:

1. Close the condenser main injection, the overboard valves, and the main circulating pump suction valve. Take necessary steps to ensure against their unauthorized opening.

2. Open the water box drain and vent connections, and drain the sea water side of the condenser.

3. Attach a pump, capable of developing a head equal to the hydrostatic test pressure for this space, to the double tube sheet drain connection. Fill the double tube sheet space with water of secondary system quality.

4. Plug or cap the vent from the space between the double tube sheet.

5. Pressurize the double tube sheet space to the hydrostatic test pressure.

CAUTION: In some designs this double tube sheet space should NOT be pressurized unless the waterbox is installed. This requirement is based upon the need for the additional strength, in accordance with manufacturer's instructions, offered by the water box bolting and the waterbox flange.

6. Carefully dry the face of the outer tube sheet, and inspect the end of each tube for indications of leakage.

7. Reroll any tube to tube-sheet joints found leaking.

CONDENSER SAFETY PRECAUTIONS

The following safety precautions should be observed in relation to all steam condensers in the engineering plant:

1. Make every effort to eliminate air leaks through all parts of the system that operate under vacuum.
2. Do not subject sea water chests to pressures in excess of 15 psig.
3. Lift by hand and examine water chest relief valves whenever condensers are secured.
4. To detect salt water leaks, constantly check the salinity indicator.
5. Keep baffle plates in place under steam inlets to condensers, and keep them in good condition.
6. Slow down or stop the engine if a loss of vacuum is accompanied by a hot or flooded condenser.
7. Do not allow water to accumulate in the condenser and overflow into the turbine.
8. Keep condensers clean and tight.
9. Before the salt water side of a condenser is opened, close all sea connections tightly and secure them against accidental opening.

10. Bring no open flame (or anything which will cause a spark) close to a newly opened condenser, until after the condenser has been thoroughly blown out with steam or air. Hydrogen or sewer gas may be present.

11. Renew deteriorated tube packing before it reaches such a condition that removal is difficult.

12. When setting up on ferrule-type tube packing, do not exert so much pressure that the tube end is necked or crimped; however, screw down the ferrules enough to keep them from backing out.

13. Be careful not to damage tube sheets when repairing tube ends or renewing tubes.

14. Keep condenser tubes clear of foreign matter.

15. Keep salt water sides of idle condensers dry, especially when the ship is in polluted waters.

16. Keep the steam side of secured condensers drained.

17. Keep the salt water sides of condensers in use free from air.

18. When boiling out and draining condensers, see that necessary safeguards are provided to protect yourself and others against being scalded.

19. Keep salinity indicator systems in constant operation.

20. Test the main circulating pump bilge suction, when directed by the engineer officer. To conduct this test, it is generally necessary only to start the main circulating pump, open the bilge suction line stop or check valve, and then close down on the sea suction line valve to about 3/4 closed, or until the maximum bilge suction capacity is obtained.

OTHER HEAT EXCHANGERS

Some of the other various heat exchangers in use aboard ship are discussed throughout this training course in relation to the specific systems of which they are a part. Information on some other shipboard heat exchangers is given in the following sections.

DEAERATING FEED TANKS

Deaerating feed tanks serve three purposes: (1) to free the condensate of oxygen and other noncondensable gases, (2) to heat the feed water, and (3) to act as a reservoir in which to store water to take care of fluctuations in feed water demand or condensate supply. Deaerating feed tanks "scrub" the feed water free of air by use of spray nozzles. The feed water is heated by direct contact with auxiliary exhaust steam. The deaerating feed tank is usually designed to operate at a pressure of about 15 psig and to heat the water to between 240° and 250° F. The water is kept just under its boiling point at the operating pressure so that it will not flash into steam.

One type of deaerating feed tank is shown in figure 8-6. Condensate enters the tank through the tubes of the vent condenser and then flows to the spray head. It is forced out through multiple spring-load spray nozzles in the spray head. The nozzles are designed to open at a very low pressure and to maintain good atomization even at very low loads. The water leaves the spray nozzles in a very fine spray and is discharged throughout the steam-filled upper section of the tank. The very small droplets of water are heated, scrubbed, and partially deaerated by the relatively air-free steam. As the steam gives up its heat to the water, much of the steam is condensed into water. The droplets of water (including both the entering condensate sprays out from the vent condenser and the steam condensed in the deaerating feed tank) are collected in a cone-shaped baffle which leads them through a central port, to the deaerating unit. Here the steam coming into the deaerating unit picks up the water and throws it radially outward and upward against the lower side of the conical baffle. In this process, the water and steam are so thoroughly mixed that the water is heated to practically the same temperature as the steam, and the dissolved gases in the water are removed. The deaerated water then falls into the storage space at the bottom of the tank, where it remains under a blanket of air-free steam until it is needed for the boilers.

Steam sweeps the air from the deaerating feed tank. The mixture of steam and air travels across the vent condenser tubes, where most of the steam is condensed into water which drops back into the deaerating tank. The air together with any remaining steam is vented to the gland exhaust condenser.

The steam control valve remains wide open during normal operation and the flow of steam into the tank is controlled by the rate of condensation. Normally the pressure drop between the auxiliary exhaust steam line and the deaerating feed tank will be 1/2 psig or less. At low loads,

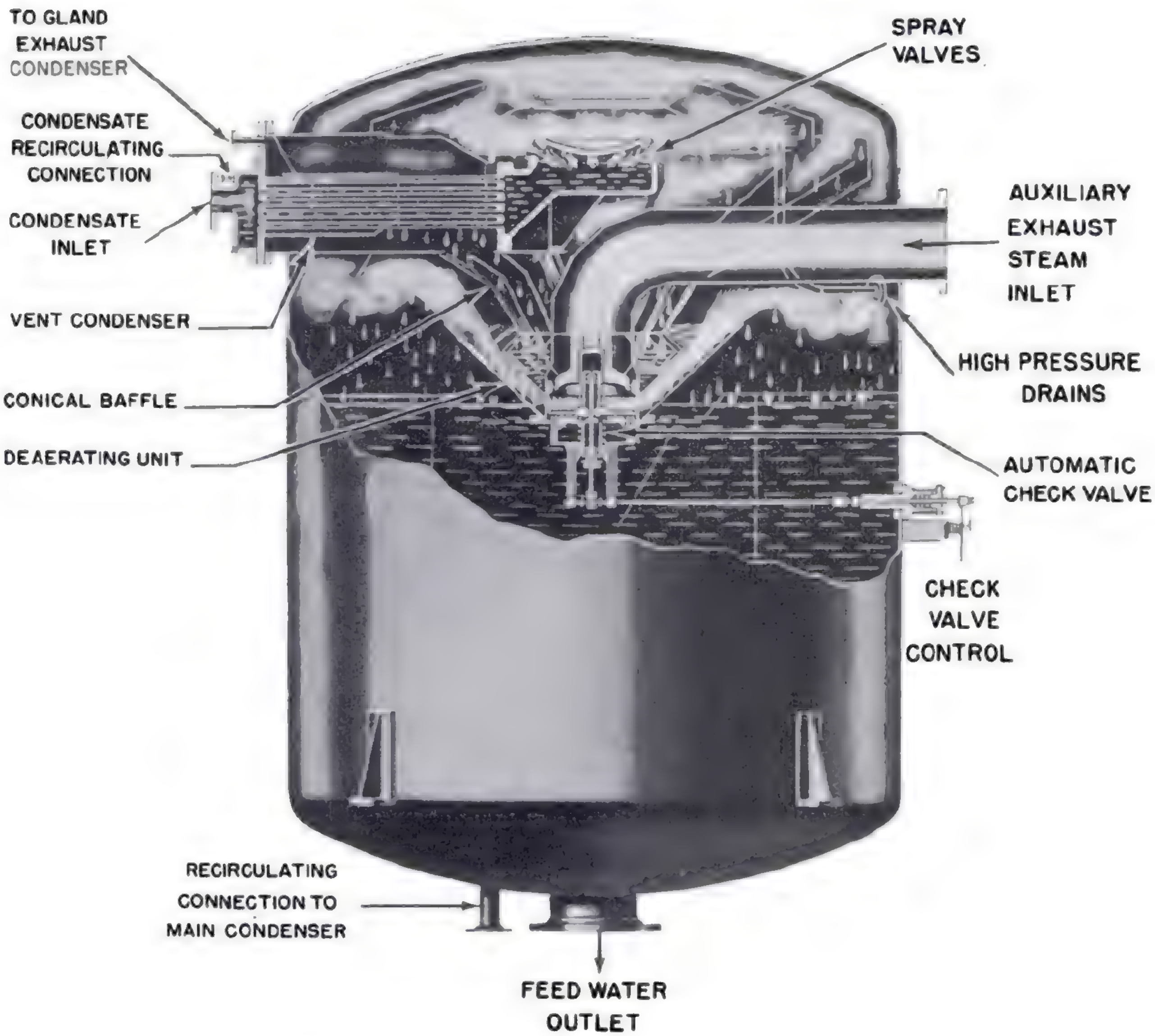

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Figure 8-6.—Elliott type deaerating feed tank.

the water overflowing the cup-shaped recess fills the space within the conical baffles. This causes a cessation of steam flow until the tank pressure has decreased, because of condensation, to a point where the pressure drop is great enough to allow steam to blast through the water in the helical baffles. At high loads, the rate of steam flow is great enough to prevent accumulation of water in the baffles; the steam drives the water out as it overflows the cup-shaped recess.

A shaft extends from the steam valve through the side of the tank; the shaft has a lever attached to it. When the lever is thrown in one direction, it presses a collar against the check valve and forces it to the fully closed position. When the lever is thrown in the opposite direction, another collar forces the check valve to the wide open position. When the lever is in the center position, the check valve is free to operate automatically.

Operation

During normal operation, the only control necessary is maintaining the proper water level. The maximum water level, beyond which the unit should never be operated, is shown in figure 8-7. If the water level is too high, the tank cannot properly remove the air from the feed water. A low water level may endanger the main feed booster pumps, the main feed pumps, and the boilers.

Deaerating feed tanks remove gases from the feed water by using the principle that the solubility of gases in feed water approaches zero when the water temperature approaches the boiling point. During operation, steam and water are mixed by spraying the water so that it comes in contact with steam from the auxiliary exhaust line. The quantity of steam must always be proportional to the quantity of water, otherwise, faulty operation or a casualty will result.

In most deaerating feed tanks, the manhole provides access for the inspection of spray nozzles; other tanks are so designed that the spray nozzle chamber and the vent condenser must be removed in order to inspect the nozzle.

Auxiliary exhaust steam flows directly into the deaerating unit. A check valve either in the deaerating tank, or in the line leading to the tank, allows the steam to flow from the auxiliary exhaust line whenever the pressure inside the deaerating tank is less than the pressure in the exhaust line. The check valve also prevents the return flow of water into the auxiliary exhaust line, in the event that the deaerating tank becomes flooded.

START-UP.—A secured deaerating tank must be kept isolated from the feed water system and its contained water must be deaerated before the tank is put into service. If the tank is empty, it may be filled by means of the emergency feed pump, taking suction from a reserve feed tank and discharging to the condensate line, or in some installations, discharging directly to the deaerating tank. During this operation, the auxiliary exhaust must be cut in to the deaerating tank to heat and deaerate the feed water.

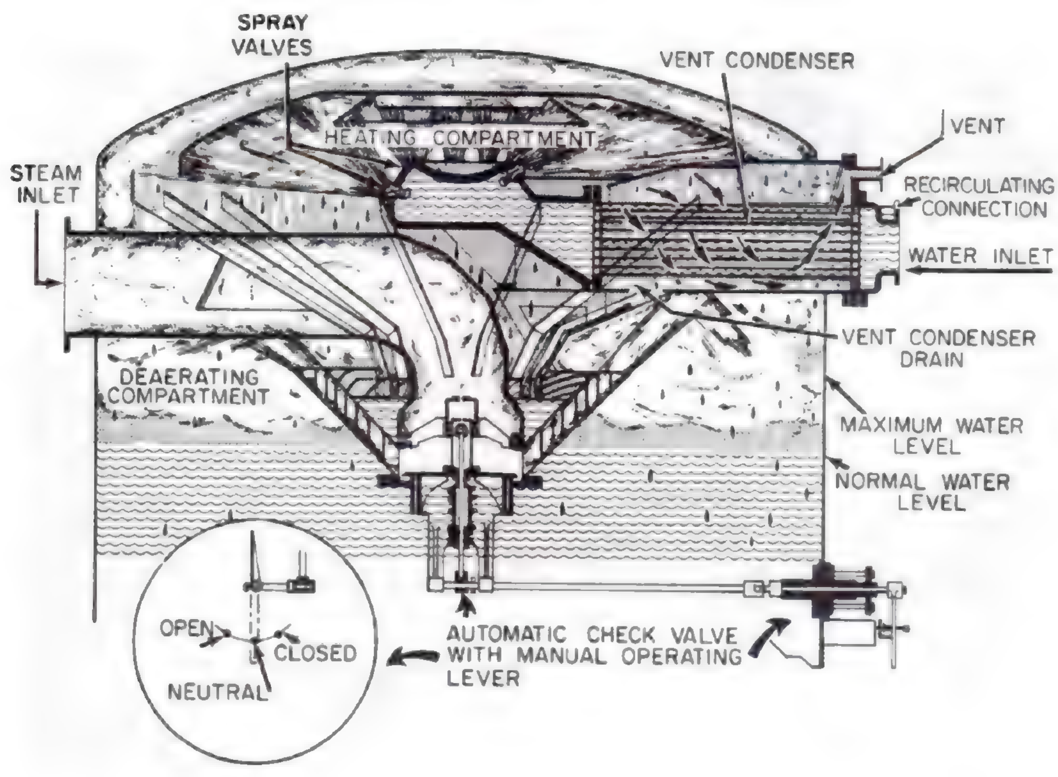

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Figure 8-7.—Deaerating feed tank (diagrammatic arrangement).

In warming up a deaerating tank, the steam and water supply valves should be opened slowly to avoid sudden temperature changes in the tank. When the tank is filled to the normal operating level, a feed booster pump should be started to recirculate the water from the deaerating tank, through the booster pump and then through the vent condenser, or directly back to the DFT, depending on the class ship. It will take about 10 minutes for this recirculation to heat the water in the tank. The deaerating tank should be operated at normal operating temperatures and pressure for a minimum of 10 minutes before it will be ready to be put into service.

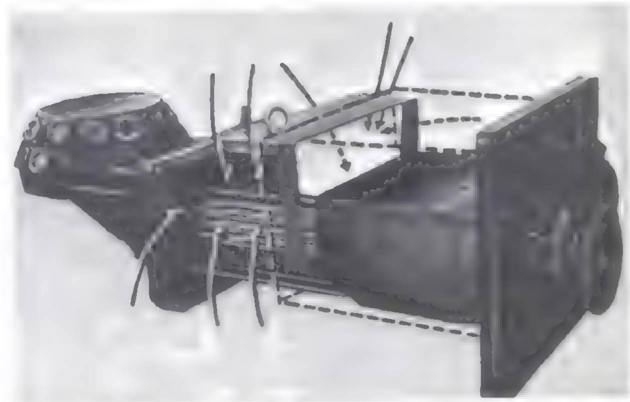
When the deaerating tank is fully warmed up, and before it is cut into the feed system, the valve in the warming up line should be closed slowly. The starting line should be closed during all normal operating. The main feed pump recirculating line is relied on to protect the booster pumps and the feed pumps. If the starting up line is left open during operation, it could reduce the main feed pump suction pressure below that required.

UNDERWAY.—In order to have effective deaeration, it is necessary to vent sufficient steam from the deaerating feed tank to sweep out all air which has been separated from the feed water. This separated air is continuously concentrated in the uncondensed portion of the steam, as the steam passes through the deaerating unit, preheater, and vent condenser. If all the steam were condensed in the vent condenser, the separated air would again mix with the condensate.

The amount of vented steam is controlled by an orifice installed in the vent line of the vent condenser. The vent line orifice must be large enough so that the minimum quantity of steam-air mixture necessary for proper deaeration is discharged when the minimum operating pressure exists in the deaerating tank.

A vent condenser, showing the path of gases into the unit, is shown in figure 8-8.

SHUTDOWN.—In securing the deaerating tank, the vent valve should be opened before the water supply is secured. When securing the water, the pressure in the tank should not be allowed to build up. Should the tank pressure rise too high for normal operation due to some external means (high pressure drains), a recirculating connection, leading from the base of the tank into the main condenser, provides increased circulation through the tank. This recirculating connection enables the water to be



96.28

Figure 8-8.—Vent condenser, showing path of gases.

discharged back into the tank, after it has been cooled by the condenser, thereby causing a reduction in pressure and temperature within the tank. Except in an emergency, the steam must not be secured before securing the water, the tank will be filled with cold water that is not deaerated. Under normal securing conditions, the vent should be shifted from the gland seal condenser to the atmosphere; if this is not done, the gland seal condenser will overheat.

Maintenance

Deaerating feed tanks should be periodically tested and inspected to ensure that they are operating efficiently. Preventive maintenance is much more economical than corrective maintenance. All preventive maintenance should be conducted in accordance with the 3-M System (PMS Subsystem). Efficient operation depends primarily on the operation of the spray valves. When testing spray valves the following items should be carefully checked:

1. The spray valve must be fully open or completely shut. Any leakage indicates faulty operation which will seriously affect deaeration. If leakage does exist the valve should be examined for scored or damaged seats or improper spring tension.

2. When the valve opens, the spray should be a complete cone. Any other form of discharge is a positive indication of faulty operation. An incomplete cone indicates cocking of the disk which may be caused by a defective spring.

3. All valves should open at the same pressure to avoid leaving gaps in the spray area. The valves and seats should be free of deposits and should operate freely in any position.

4. When test procedures described in the Naval Ships Technical Manual are used, the results will not be definitive, however, they will indicate MAJOR malfunctioning of the unit. All naval shipyards have the equipment and personnel to perform proper tests for more positive results. For any test results to be of value, all testing should be accomplished with samples taken from an operating deaerating feed tank feeding a steaming boiler.

In the construction of deaerating feed tanks, as many parts as possible are welded together but some bolts and nuts are used. When parts are assembled, all nuts should be secured with split pins. Split pins must be of a corrosion-resistant metal such as Monel or stainless steel. Ordinary steel will corrode too rapidly to give satisfactory service.

A screen is installed in the bottom of the deaerating feed tank (booster pump suction) so that if an internal part of the tank should come loose, or if metal from the condensate or steam system should enter the tank, the screen will prevent the part from entering the booster pump suction.

A MANHOLE in the shell provides access to the interior of the tank. All removable parts of the tank section are small enough to be taken out through this manhole.

The vent condenser can be removed as a unit by breaking the flanges on the condensate inlet, the vent line, and the recirculating line, then removing the vent condenser flange bolts and pulling the vent condenser out. The spray chamber and spray nozzles are attached to the vent condenser and are removed as a unit.

For safety purposes, all deaerating feed tanks are equipped with two spring-loaded relief valves. One is to prevent a high pressure from accidentally building up inside the tank, and the other, called a vacuum breaker, is to prevent a high vacuum from developing inside the tank. The vacuum breaker allows atmospheric air to enter the tank whenever the vacuum exceeds a predetermined amount.

The steam control valve automatically controls the amount of steam admitted to the deaerating tank. There are many different arrangements of these valves; this publication does not contain information on the repair procedures for each type. For complete information on each type of steam control valve, refer to the manufacturer's technical manual for the specific installation.

GLAND EXHAUST CONDENSER

In order to recover the steam expelled by the turbine glands and the deaerating feed tank, a gland leak-off and vent and drain system is installed. By means of this system the recovered steam is returned to the feed system in the form of condensate. The gland leak-off steam is led to the GLAND EXHAUST CONDENSER, where the vapors are condensed and led to the fresh water drain collecting tank. Air is drawn off from the gland exhaust condenser by a small motor-driven fan GLAND EXHAUSTER, which provides a positive discharge through piping to the atmosphere above decks.

MAIN LUBE OIL COOLERS

Main lube oil coolers are usually of the shell-and-straight-tube type and may be of single-pass or multipass construction. In modern naval ships, the main lube oil coolers are installed horizontally as illustrated in figure 8-9. The size of an oil cooler depends upon the quantity of heat that must be removed per unit of time from the lube oil in order to maintain proper bearing temperature.

The lube oil cooler consists of a cylindrical shell with a header at each end. Inside the shell is a bundle of straight, copper-nickel tubes through which the cooling water flows from one header to the other. Hot lube oil enters at the top of the shell, at the end opposite the water outlet, and flows across the tubes and around the annular jacket. The cooled oil comes out of the top of the cooler at the other end, near the water inlet. The baffles and tube support plates direct the oil flow.

On older ships, a bypass valve is installed in the oil inlet line to the cooler. The purpose of this bypass is to isolate the cooler in event of a cooler casualty. On more modern ships, the main lube oil is heated with the purifier heater.

TURBOGENERATOR LUBE OIL COOLERS

Turbogenerator lube oil coolers are similar to main lube oil coolers in construction. A three-way selector valve is placed in the oil

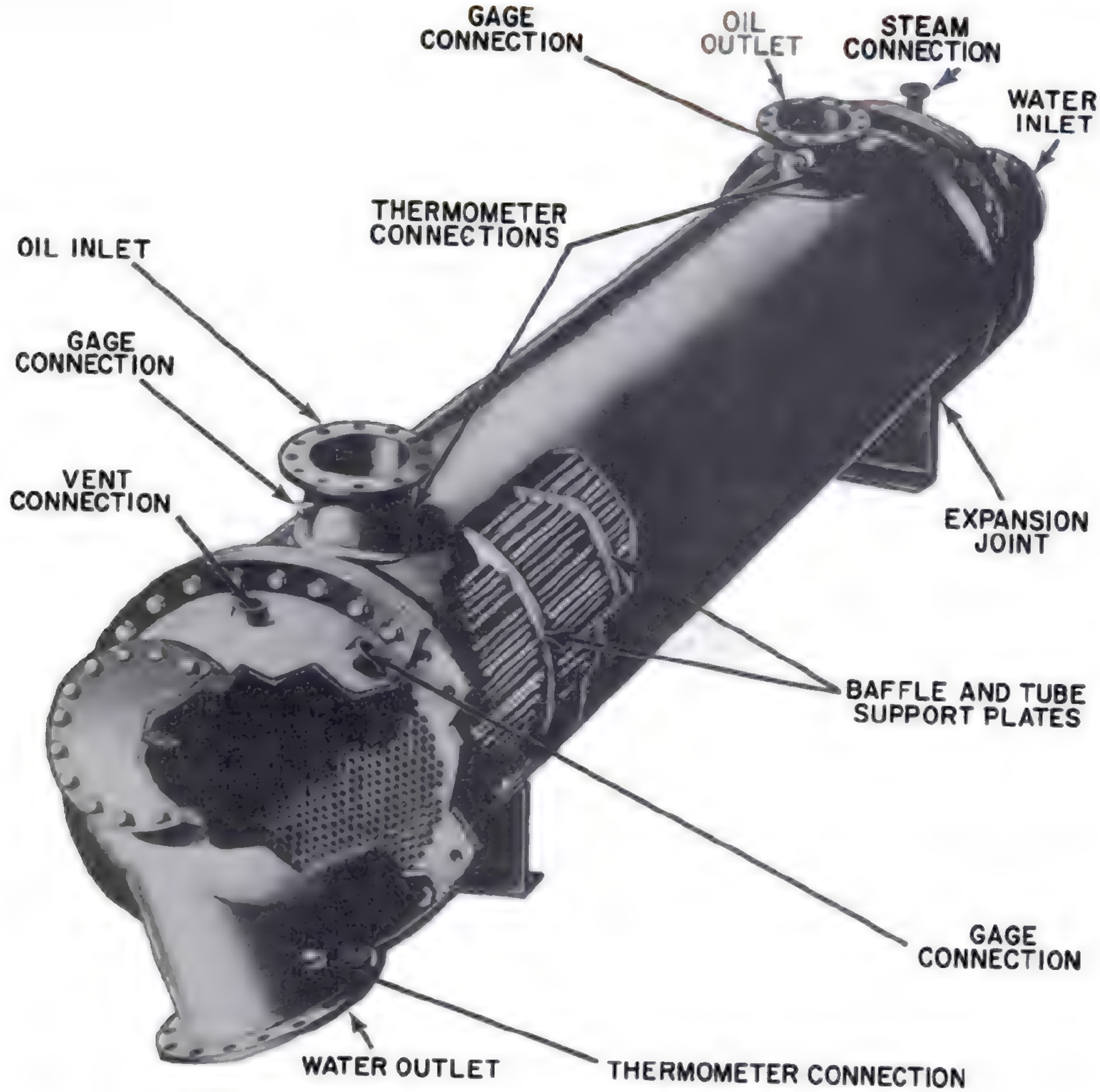


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Figure 8-9.—Main lube oil cooler.

line to route oil through the cooler or to bypass oil around the cooler. Each turbogenerator is served by a single lube oil cooler.

Sea water is pumped through the turbogenerator lube oil cooler by the auxiliary condenser circulating pump. If this pump should fail, cooling water may be taken from the firemain through a cooling water reducer which can be regulated to the desired pressure.

PUMP LUBE OIL COOLERS

Lube oil coolers for pumps may be of the shell-and-tube type, the strut tube type, or the plate type. A strut tube type cooler and a plate type cooler are shown in figure 8-10. Small lube oil pump coolers are usually multitube single-pass coolers. In some, the water flows through the tubes and the lube oil flows through the shell; in others, the water flows through the shell and the lube oil flows through the tube.

Part A of figure 8-10, shows a strut tube type oil cooler in which the water passes through the tubes. In this cooler, heat transfer is accelerated by stamped dimples in the strut tube plates. The strut tube plates are assembled so that the convex sides of the dimples touch.

Part B of figure 8-10 illustrates a plate type oil cooler for a pump. In this type of cooler the lube oil passes through the tubes. The grid distributor strip accelerates the transfer of heat from the tubes.

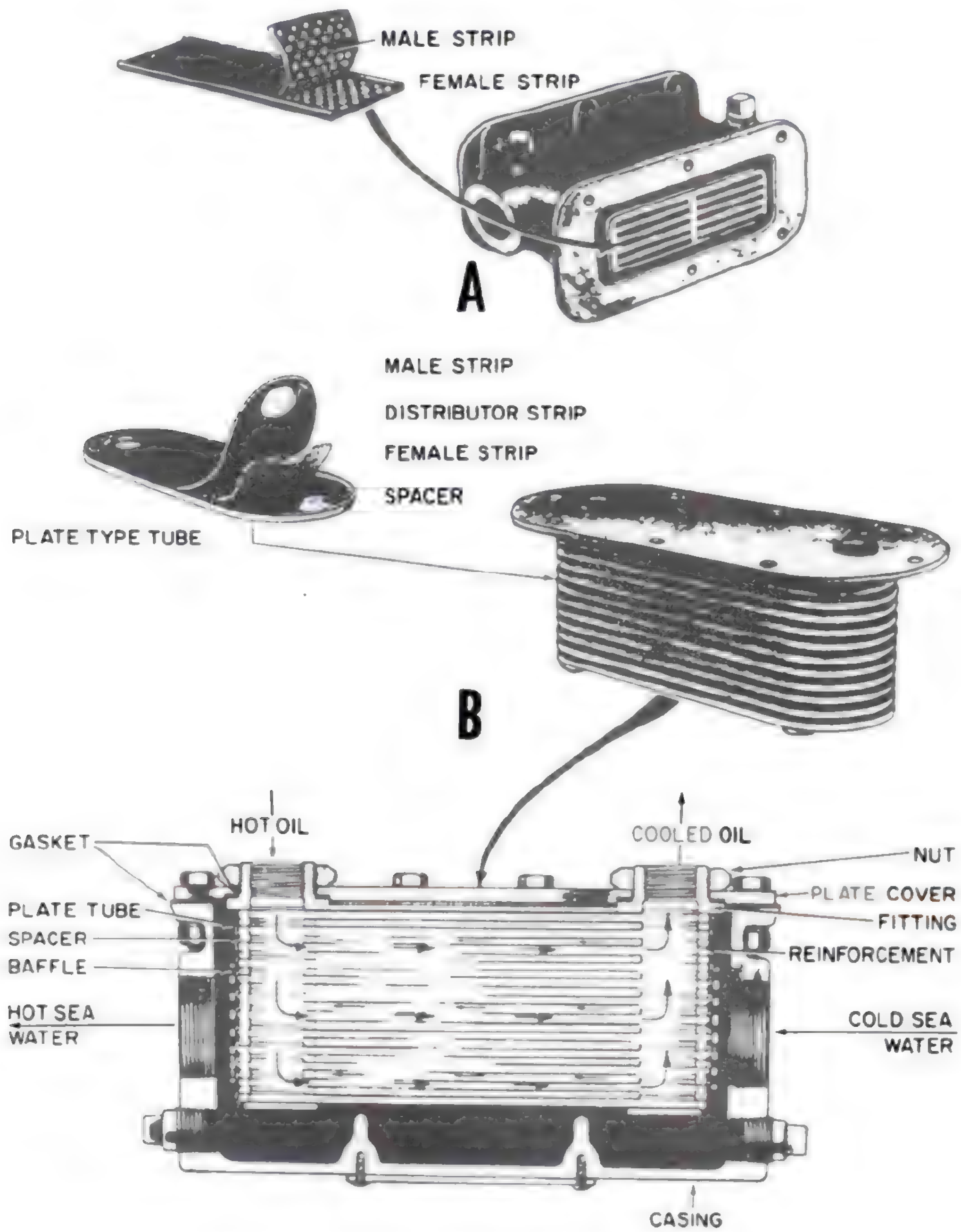

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Figure 8-10.—Oil coolers for pumps. A. Strut lube type oil cooler. B. Plate type oil cooler.

Strut tube coolers and plate tube coolers have replaceable core assemblies, and several spare core assemblies are usually carried on board ship. In practically all cases of failure of these types of coolers, core replacement is all that is required to correct the trouble. It is seldom necessary to replace the entire cooler.

AIR COOLERS

Air coolers are installed on shipboard propulsion motors and generators to keep them from overheating. The air cooler is connected to the air intake and air discharge openings of the motor or generator by suitable ducts. The only

characteristic difference between a lube oil cooler and a propulsion motor or generator air cooler is that the latter is of double-tube construction with the outer tubes having high fins.

The air cooler consists of double-wall fin tubes through which the cooling water flows. The ends of the tubes at the front and rear of the cooler are enclosed by headers. Cooling water may make one or more passes through the cooler. Hot air from the motor or generator passes through the air cooler tube bank in a path perpendicular to the tubes (fig. 8-11).

The tubes are of double-wall construction. The inner tube is of a copper-nickel alloy and the outer tube is made of brass or other non-ferrous material. The smooth-surfaced inner tube carries the water. The outer tube has internal

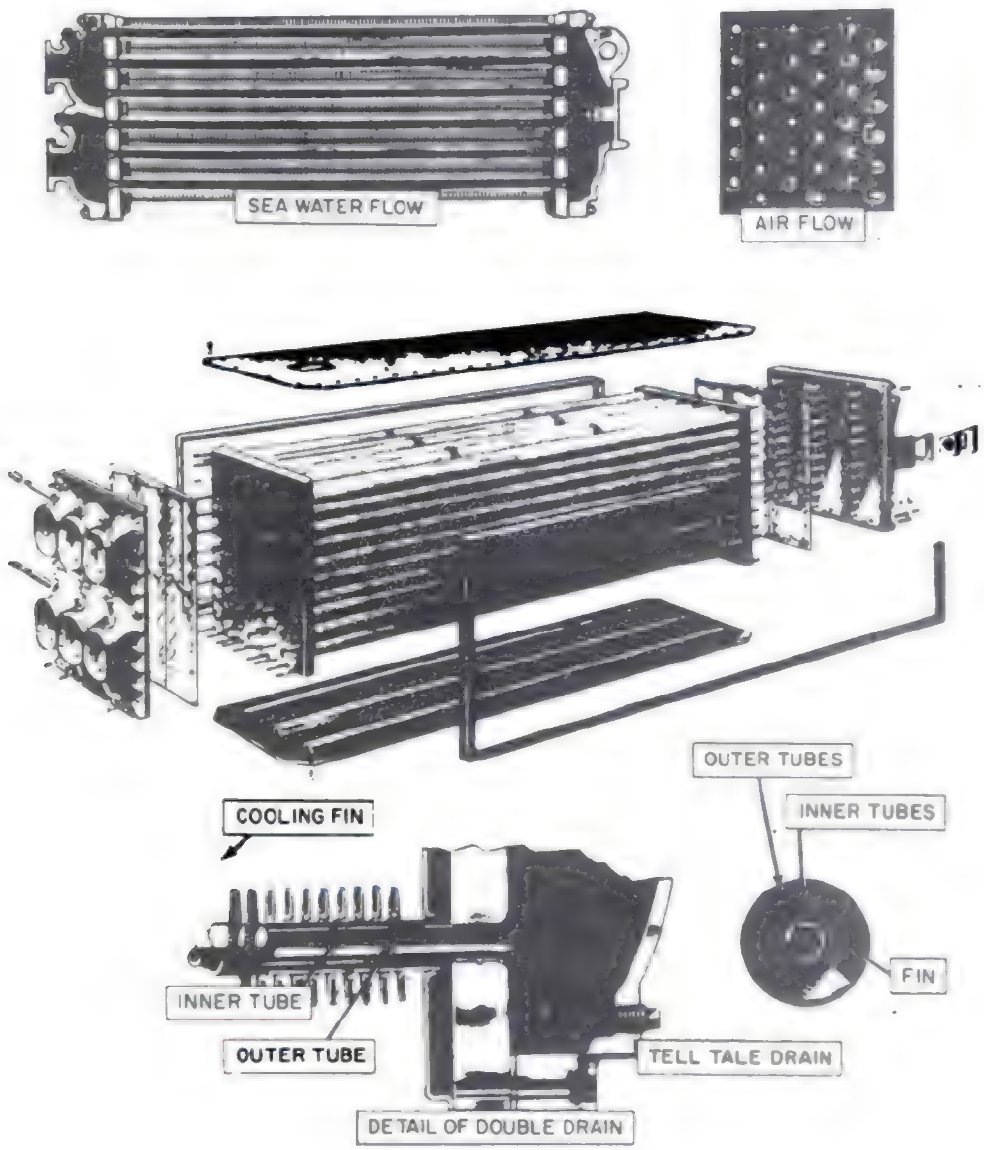

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Figure 8-11.—Air cooler for a motor or generator.

longitudinal ribs or lands which make contact with the outer surface of the inner tube. The internal ribs of the outer tube and the cooling fins mounted on the outside surface of the outer tube facilitate the transfer of heat to the cooling water.

Failure of an inner tube can be detected by water leaking from the telltale drains in the front and rear headers.

At the bottom of the front header, and to the right of the leakage drain plug, is a connection for draining water from the cooler. At the top of the front and rear header is a vent plug. These air relief plugs should be removed whenever the cooler, after having been drained of water, is to be refilled. The plugs should be removed from the telltale drain system to allow detection of leaks from the tube section of the cooler.

AIR EJECTORS

The function of an air ejector is to remove air and other noncondensable gases from the condenser. An air ejector is a type of jet pump, containing no moving parts. The flow through the air ejector is maintained by a jet of high velocity steam passing through a nozzle (fig. 8-12). The auxiliary steam systems.

The air ejector assembly used to remove air from the main condenser usually consists of a first-stage air ejector, an inter condenser, a second-stage air ejector, and an after condenser.

In most ships, however, the first and second stages of the air ejectors and their condensers have been combined into one complete assembly, such as is shown in figure 8-13. In many ships, the gland exhaust condenser has been incorporated within the shell of the after condenser. The shell is rectangular, and is divided by a longitudinal plate into the intercondenser and the after-condenser sections. A baffle at the gland vapor inlet deflects the air and vapor downward over the lower bank of tubes in the after-condenser section.

In order to provide for continuous operation, two sets of nozzles and diffusers are furnished for each stage of the air ejectors. Only one set is necessary for operation of the plant; the other set is maintained ready for use in case of damage or unsatisfactory operation of the set in use.

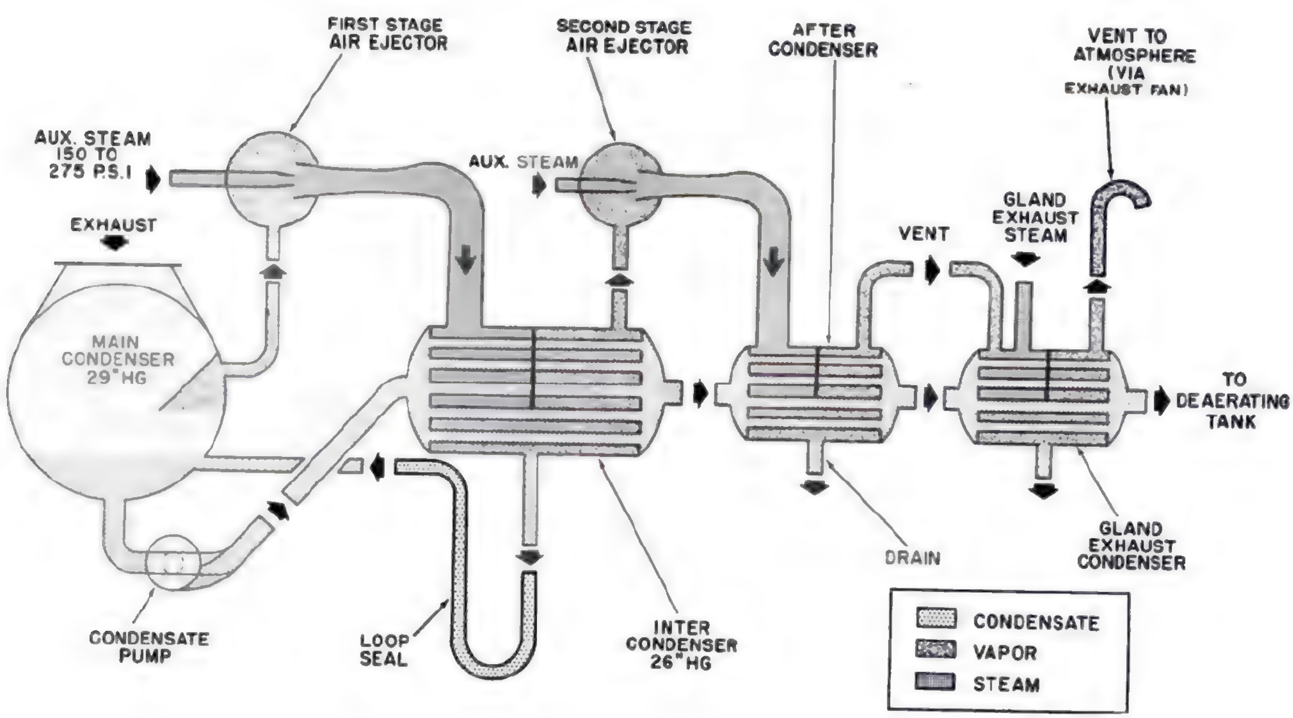

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Figure 8-12.—Flow diagram of a two-stage air ejector.

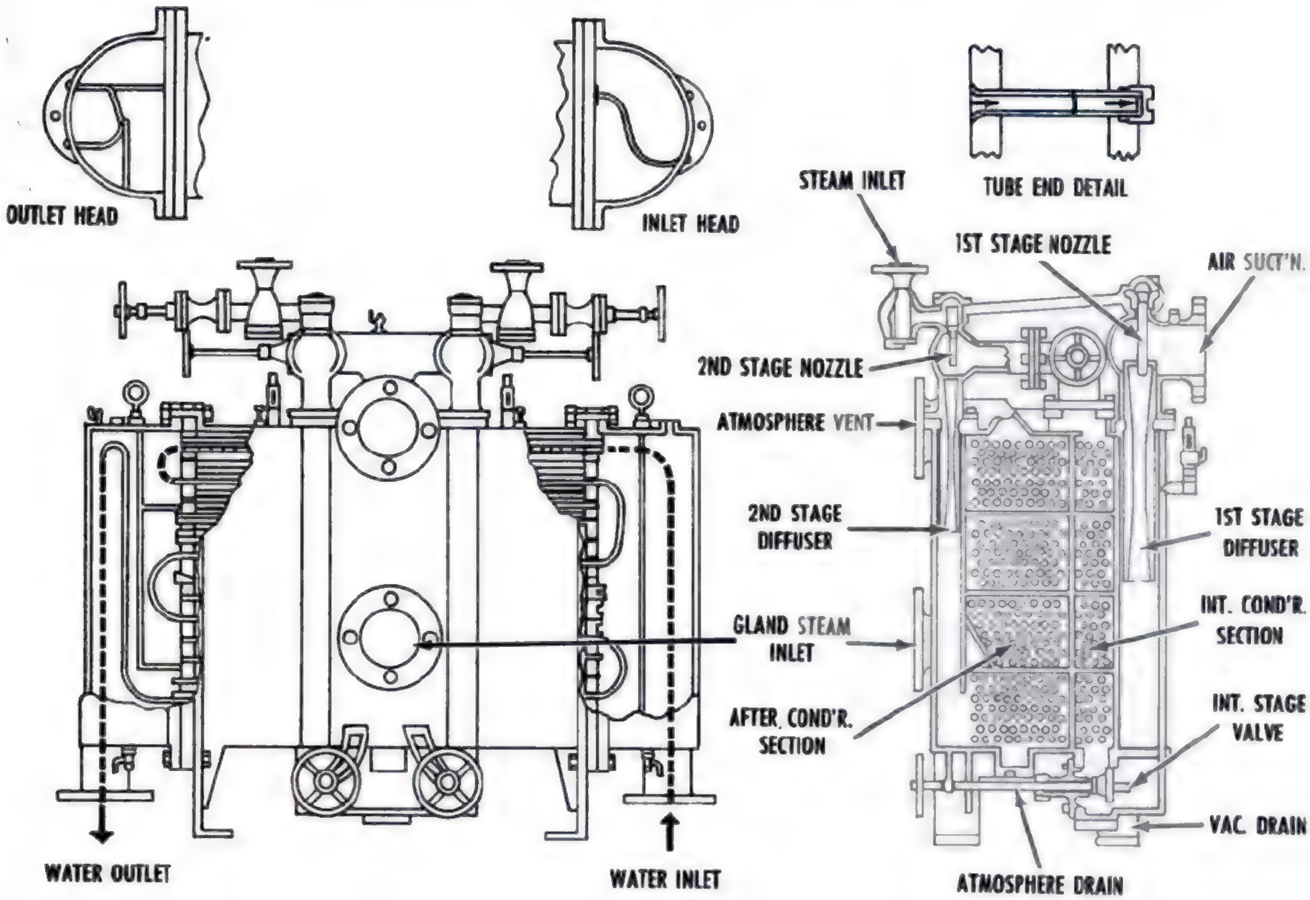

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Figure 8-13.—A main air ejector and condenser assembly.

The two sets can be used simultaneously when excessive air leakage into the condenser necessitates additional pumping capacity.

An inter stage valve is provided between the discharge of each first-stage ejector and the inter condenser so that the pressure built up by the first-stage jet, in operation, will not be lost back to the condenser through the idle first stage. For a similar reason, a cutout valve is located between each second-stage suction chamber and the inter condenser. By means of diaphragm plates in the inlet and outlet heads, the cooling water (condensate) is forced to make several passes through the unit before being discharged.

The atmospheric vent is usually connected to the suction of a small motor-driven fan (gland exhauster), which provides a positive discharge through piping to the atmosphere above decks. This is necessary to avoid filling the engineroom with steam should the air ejector cooling water supply fail, thereby allowing the steam to pass through the inter condenser and after condenser without being condensed.

PRINCIPLES OF OPERATION

The first-stage air ejector takes suction on the main condenser and discharges the steam-air mixture to the inter condenser, where the steam content of the mixture is condensed. The resulting condensate drops to the bottom of the inter condenser shell, and from there it drains to the main condenser through a U-shaped loop seal line. The air passes to the second-stage air ejector suction.

In the second-stage air ejector, another jet of steam is used. The steam-air mixture is now

discharged into the after condenser, where the steam is condensed and the air is vented to the atmosphere. (Normally, the air is vented to the atmosphere by way of the gland exhaust condenser; however, in some installations it is vented directly to the atmosphere from the air ejector after condenser).

Condensate from the main condenser is used as the cooling water in the air ejector inter and after condensers. The air ejectors remove air only from the condenser, not from the condensate.

The inter condenser is under vacuum of about 26 inches of mercury. The after condenser is at approximately atmospheric pressure.

To assure sufficient cooling water for proper operation of the air ejectors when raising vacuum standing by, and at fractional power (cruising), a condensate recirculating line and valve are installed at the cooling water outlet from the after condenser or on the vent condenser inlet header. To make recirculation automatic, and to avoid overheating of the air ejector condenser, most air ejector recirculating lines are fitted with thermostatically controlled valves, discussed in chapter 7 of this training manual.

A manually controlled valve allows bypassing of the thermostatic recirculating valve during the warming-up period. This bypass valve is also used in case the thermostatic valve is inoperative. When the required condenser vacuum is obtained, the manually controlled bypass valve is secured. Under normal operating conditions, recirculation to the main condenser at light loads is automatically controlled by the thermostatic recirculating valve.

As previously noted, the condensate formed in the inter condenser is returned to the main condenser through the loop seal. If there was a direct connection between the inter condenser and the main condenser, the vacuum would be equalized in the two condensers. Since the main condenser carries a higher vacuum than the inter condenser, it is necessary that some form of seal be maintained in this drain line to prevent this equalization of vacuum. A water level in the U-shaped loop seal line provides this seal.

STARTING AIR EJECTORS

Manufacturers' technical manuals are furnished to provide information on the proper operation of all air ejector installations. The procedure for starting the air ejectors is usually as follows:

1. Start circulation of condensate cooling water through the air ejector condenser.
2. Open the valves in the drain lines, from the inter and after condensers.
3. Check the valves in the pressure and vacuum gage lines to be sure they are open.
4. Lift relief valves by hand.
5. Open the second-stage discharge valve.
6. Drain the steam supply lines to the air ejector assembly.
7. Cut in the steam to the second stage. Be sure that the steam is at or slightly above designed pressure).
8. Open the second-stage suction valve.
9. When the main condenser vacuum reaches 20 inches (or when ordered by the officer of the watch), open the first-stage discharge valve.
10. Cut in the steam to the first stage.
11. Open the first-stage suction valve.

Upon completion of the preceding procedure, the ejector should be in full operation and the main condenser vacuum should rapidly rise to that normally obtainable under standby conditions.

Discharge valves should always be opened before steam is admitted to the air ejector nozzles, and the steam supply should always be shut off before the discharge valves are closed.

After an air ejector has been started properly, it requires very little attention. It is necessary to (1) supply dry steam at designed pressure, (2) provide sufficient cooling water through the air ejector condenser tubes, (3) maintain proper drainage of the inter and after condensers, and (4) maintain a proper water level in the loop seal line.

SHIFTING AIR EJECTORS

Should it become necessary or desirable to shift from one two-stage air ejector unit to another while an air ejector unit is in operation, the procedure is as follows:

1. Open the discharge valve of the standby second stage.
2. Open the second-stage steam inlet valve.
3. Open the second-stage suction valve.
4. Open the first-stage discharge valve.
5. Open wide the steam inlet valve to the first-stage nozzle.
6. Open wide the suction valve of the first-stage element.

At this point both two-stage units are in operation in parallel. The following procedure applies to the air ejector unit to be secured:

1. Close the suction valve of the first stage.
2. Close the steam supply valve to the first stage.
3. Close the discharge valve of the first stage.
4. Close the suction valve of the second stage.
5. Close the steam to the second stage.
6. Close the discharge valve of the second stage.

This completes the operation. If the turbine (and consequently the condenser) is operating at a low or medium rate when the air ejectors are shifted, it may be necessary to recirculate condensate during the time when both two-stage units are in service in order to provide sufficient cooling water for the inter and after condensers. If sufficient cooling water is provided, or if the valves are opened and closed in the wrong order, a loss of vacuum will result and there is a possibility of putting excessive pressure on the air ejector condensers.

SECURING AIR EJECTORS

When securing an air ejector assembly, proceed as follows:

1. Close the first-stage suction valve.
2. Close the first-stage steam inlet valve.
3. Close the first-stage discharge valve.
4. Close the second-stage suction valve.
5. Close the second-stage steam valve.
6. Close the second-stage discharge valve.
7. Close the inter and after condenser drains.

CARE AND MAINTENANCE OF AIR EJECTORS

If an air ejector fails to maintain the proper vacuum, the cause may be traced to one of the following difficulties.

1. FAULTY STEAM PRESSURE.—If the pressure fluctuates and falls below standard, raise it to a point not over 15 psi above the designed pressure. Too high a pressure can also cause a reduced capacity, may overload the condenser units, and will cause an uneconomical quantity of steam to be used.

2. CLOGGED STEAM STRAINERS.—Strainers provided ahead of the nozzles must be clean. (NOTE: It is possible to clean or replace steam strainers as well as nozzles, of an air ejector assembly while the rest of the unit is in operation. It is necessary to isolate the unit which is to be opened from the rest of the assembly, by closing the steam supply valve and the inter stage valves of this unit, to avoid burns being suffered by personnel engaged in this work.) Strainers should be cleaned in accordance with the 3-M System or manufacturers' instructions.

3. INSUFFICIENT COOLING WATER.—If enough cooling water is not circulated through the air ejector inter and after condensers, a loss in vacuum results. This happens because the water becomes heated and will not condense the steam content of the air-vapor mixture entering the inter condenser. The second-stage ejector becomes overloaded because, instead of handling only air, it must also handle some steam which is not condensed in the inter condenser. Watch the temperature of the cooling water at the cooling water outlet, and keep it at the temperature designated by the manufacturer.

4. LEAKAGES.—Air leaks through the suction or discharge valves result in a loss of vacuum due to overloading of the air ejector. Leaks in valve glands, gasketed joints, relief or sentinel valves, etc., will have the same results.

Flooding of the inter or after condenser shell with the condensate whether caused by leaking tubes in the inter or after condenser or by improper drainage, will interrupt the removal of air and cause loss of vacuum.

Tube joint leakage can be remedied by repacking the tube ends with new packing rings.

5. FOULED NOZZLES.—Erosion or fouling of air ejector nozzles is evidence that wet steam is being admitted to the equipment. The faulty nozzles make it impossible to operate the ejector under a high vacuum. In some instances, the nozzles may be clogged with grease, boiler compound, or some other deposit which will decrease the jet efficiency. If there are grease deposits the nozzles should be cleaned by soaking them in an approved solvent.

6. UNSTABLE LOOP SEAL.—An air leak in the U-shaped loop seal provided for draining the inter condenser causes an unstable seal.

Occasionally a violent roll of the ship may cause the water in the seal to siphon out into the condenser. A connection on the condensate line is provided for filling the loop seal line.

AIR EJECTOR SAFETY PRECAUTIONS

The following safety precautions should be observed for air ejectors:

1. When starting an air ejector, always open the discharge valves before admitting steam to the nozzles. When securing an air ejector, always close tightly the steam supply valves to the nozzles before closing the discharge valves.

2. Before starting an air ejector, always drain the steam supply line, open the drain valves in the inter and after condenser drain lines and be sure the atmospheric vent line is clear.

3. Should retubing or any other major repairs to an air ejector assembly be necessary, all parts should be hydrostatically tested following reassembly.

CHAPTER 9

LUBRICATION AND ASSOCIATED EQUIPMENT

Lubrication reduces friction between moving parts by substituting fluid friction for solid friction. Without lubrication, it is difficult to move a hundred-pound weight across a rough surface; with lubrication, and with proper attention to the design of bearing surfaces, it is possible to move a million-pound load with a motor that is small enough to be held in the hand. By reducing friction, lubrication reduces the amount of energy required to perform mechanical actions and also reduces the amount of energy that is dissipated as heat.

Lubrication is a matter of vital importance throughout the shipboard engineering plant. Moving surfaces must be steadily supplied with the proper kinds of lubricants. Lubricants must be maintained at specified standards of purity, and at designed pressures and temperatures in the lubrication systems. Without adequate lubrication, a good many units of shipboard machinery would quite literally grind to a screeching halt.

The lubrication requirements of shipboard machinery are met in various ways, depending upon the nature of the machinery. This chapter deals with the basic principles of lubrication, the lubricants used aboard ship, the lubrication systems installed for many shipboard units, and the devices used to maintain lubricating oils in the required condition of purity.

FRICTION

The friction that exists between a body at rest and the surface upon which it rests is called static friction. The friction that exists between moving bodies (or between one moving body and a stationary surface) is called kinetic friction. Static friction, which must be overcome to put any body in motion, is greater than kinetic friction, which must be overcome to keep the body in motion.

There are three types of kinetic friction: sliding friction, rolling friction, and fluid friction. Sliding friction exists when the surface of one solid body is moved across the surface of another solid body. Rolling friction exists when a curved body such as a cylinder or a sphere rolls upon a flat or curved surface. Fluid friction is the resistance to motion exhibited by a fluid.

Fluid friction exists because of the cohesion between particles of the fluid and the adhesion of fluid particles to the object or medium which is tending to move the fluid. If a paddle is used to stir a fluid, for example, the cohesive forces between the molecules of the fluid tend to hold the molecules together and thus prevent motion of the fluid. At the same time, the adhesive forces of the molecules of the fluid cause the fluid to adhere to the paddle and thus create friction between the paddle and the fluid. Cohesion is the molecular attraction between particles that tends to hold a substance or a body together; adhesion is the molecular attraction between particles that tends to cause unlike surfaces to stick together. From the point of view of lubrication, adhesion is the property of a lubricant that causes it to stick (or adhere) to the parts being lubricated; cohesion is the property which holds the lubricant together and enables it to resist breakdown under pressure.

Cohesion and adhesion are possessed by different materials in widely varying degrees. In general, solid bodies are highly cohesive but only slightly adhesive. Most fluids are quite highly adhesive but only slightly cohesive; however, the adhesive and cohesive properties of fluids vary considerably.

FLUID LUBRICATION

Fluid lubrication is based on the actual separation of surfaces so that no metal-to-metal contact occurs. As long as the lubricant

film remains unbroken, sliding friction and rolling friction are replaced by fluid friction.

In any process involving friction, some power is consumed and some heat is produced. Overcoming sliding friction consumes the greatest amount of power and produces the greatest amount of heat. Overcoming rolling friction consumes less power and produces less heat. Overcoming fluid friction consumes the least power and produces the least amount of heat.

LANGMUIR THEORY

A presently accepted theory of lubrication is based on the Langmuir theory of the action of fluid films of oil between two surfaces, one or both of which are in motion. Theoretically, there are three or more layers or films of oil existing between two lubricated bearing surfaces. Two of the films are boundary films (indicated as I and V in part A of fig. 9-1), one of which clings to the surface of the rotating journal and one of which clings to the stationary lining of the bearing. Between these two boundary films are one or more fluid films (indicated as II, III, and IV in part A of fig. 9-1). The number of fluid films shown in the illustration is arbitrarily selected for purposes of explanation.

When the rotating journal is set in motion (part B of fig. 9-1), the relationship of the journal to the bearing lining is such that a wedge of oil is formed. The oil films II, III, and IV begin to slide between the two boundary films, thus continuously preventing contact between the two metal surfaces. The principle is again illustrated in part C of figure 9-1, where the position of the oil wedge W is shown with respect to the position of the journal as it starts and continues in motion.

The views shown in part C of figure 9-1 represent a journal or shaft rotating in a solid bearing. The clearances are exaggerated in the drawing in order to illustrate the formation of the oil film. The shaded portion represents the clearance filled with oil. The film is in the process of being squeezed out while the journal is at rest, as shown in the stationary view. As the journal slowly starts to turn and the speed increases, oil adhering to the surfaces of the journal is carried into the film, increasing the film thickness and tending to lift the journal as shown in the starting view. As the speed increases, the journal takes the position shown in the running view. Changes in temperature,

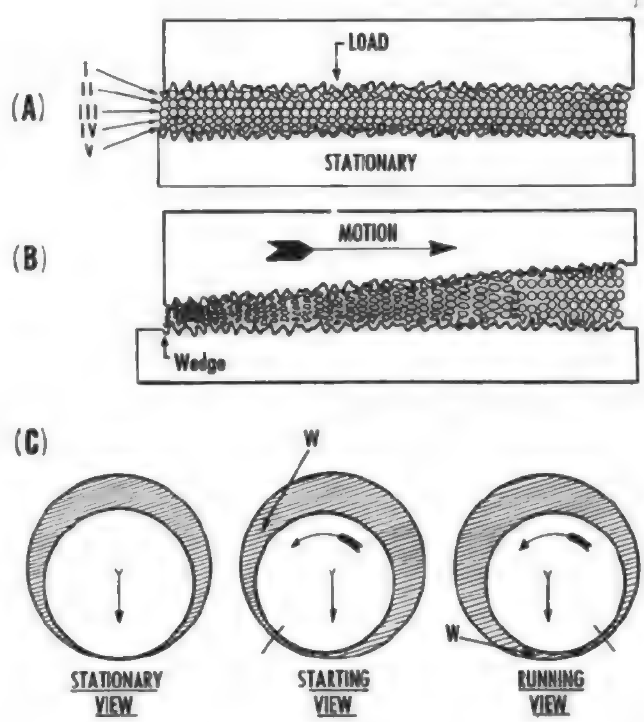

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Figure 9-1.—Oil film lubrication. (A) Stationary position, showing several oil films; (B) surface set in motion, showing principle of oil wedge; (C) principle of (A) and (B) shown in a journal bearing.

with consequent changes in oil viscosity, cause changes in the film thickness and in the position of the journal.

If conditions are correct, the two surfaces are effectively separated, except for a possible momentary contact at the time the motion is started.

FACTORS AFFECTING LUBRICATION

A number of factors determine the effectiveness of oil film lubrication, including such things as pressure, temperature, viscosity, speed, alignment, condition of the bearing surfaces, running clearances between the bearing surfaces, starting torque, and the nature of purity of the lubricant. Many of these factors are interrelated and interdependent. For example, the viscosity of any given oil is affected by temperature and the temperature is affected by

running speed; hence the viscosity is partially dependent upon the running speed.

A lubricant must be able to stick to the bearing surfaces and support the load at operating speeds. More adhesiveness is required to make a lubricant adhere to bearing surfaces at high speeds than at low speeds. At low speeds, greater cohesiveness is required to keep the lubricant from being squeezed out from between the bearing surfaces.

Large clearances between bearing surfaces require high viscosity and cohesiveness in the lubricant to ensure maintenance of the lubricating oil film. The larger the clearance, the greater must be the resistance of the lubricant to being pounded out, with consequent destruction of the lubricating oil film.

High unit load on a bearing requires high viscosity of the lubricant. A lubricant subjected to high loading must be sufficiently cohesive to hold together and maintain the oil film.

LUBRICANTS

Although there is growing use of synthetic lubricants, the principal source of the oils and greases used in the Navy is still petroleum. By various refining processes, lubricating stocks are extracted from crude petroleum and blended into a multiplicity of products to meet all lubrication requirements. Various compounds or additives are used in some lubricants (both oils and greases) to provide specific properties required for specific applications.

Types of Lubricating Oils

Lubricating oils approved for shipboard use are limited to those grades and types deemed essential to provide proper lubrication under all anticipated operating conditions.

For diesel engines, it is necessary to use a detergent-dispersant type of additive oil in order to keep the engines clean. In addition, these lubricating oils must be fortified with oxidation inhibitors and corrosion inhibitors to allow long periods between oil changes and to prevent corrosion of bearing materials.

For steam turbines, it is necessary to have an oil of high initial film strength. This oil is then fortified with anti-foaming additives and additives that inhibit oxidation and corrosion. In addition, it is necessary to use extreme pressure (EP) additives to enable the oil to carry the extremely high loading to which it is subjected in the reduction gear.

For the hydraulic systems in which petroleum lubricants are used, and for general lubrication use, the Navy uses a viscosity series of oils reinforced with oxidation and corrosion inhibitors and anti-foam additives. The compounded oils, which are mineral oils to which such products as rape seed, tallow, or lard oil are added, are still used in deck machinery and in the few remaining steam plants that utilize reciprocating steam engines.

A great many special lubricating oils are available for a wide variety of services. These are listed in the Federal Supply Catalog. Among the more important specialty oils are those used for lubricating refrigerant compressors. These oils must have a very low pour point and be maintained with a high degree of freedom from moisture.

The principal synthetic lubricants currently in naval use are (1) a phosphate ester type of fire-resistant hydraulic fluid, used chiefly in the deck-edge elevators of carriers (CVAs); and (2) a water-base glycol hydraulic fluid used chiefly in the catapult retracting gears.

Classification of Lubricating Oils

The Navy identifies lubricating oils by symbols. Each identification number consists of four digits (and, in some cases, appended letters). The first digit indicates the class of oil according to type and use; the last three digits indicate the viscosity of the oil. The viscosity digits are actually the number of seconds required for 60 milliliters of the oil to flow through a standard orifice at a specified temperature. The symbol 3080, for example, indicates that the oil is in the 3000 series and that a 60-ml sample flows through a standard orifice in 80 seconds when the oil is at a specified temperature (210°F, in this instance). To take another example, the symbol 2135 TH indicates that the oil is in the 2000 series and that a 60-ml sample flows through a standard orifice in 135 seconds when the oil is at a specified temperature (130°F, in this case).

The letters H, T, TH, or TEP added to a basic symbol number indicate that the oil contains additives for special purposes.

Lubricating Oil Characteristics

Lubricating oils used by the Navy are tested for a number of characteristics, including viscosity, pour point, flash point, fire point, auto-ignition point, neutralization number, demulsibility, and precipitation number. Standard test methods are used for making all tests. The characteristics of lube oil are briefly explained in the following paragraphs.

The VISCOSITY of an oil is its tendency to resist flow or change of shape. A liquid of high viscosity flows very slowly. In variable climates automobile owners, for example, change oils in accordance with prevailing seasons because heavy oil becomes too sluggish in cold weather, and light oil becomes too fluid in hot weather. The higher the temperature of an oil, the lower its viscosity becomes; lowering the temperature increases the viscosity. The high viscosity or stiffness of the lube oil on a cold morning makes an engine difficult to start.

If an oil of a higher viscosity is used under such conditions, the increased internal friction will raise the temperature and reduce the viscosity of the oil. The viscosity must always be high enough to keep a good oil film between the moving parts—otherwise, there will be increased friction, power loss, and rapid wear on the parts. Oils are graded by their viscosities at a certain temperature—by noting the number of seconds required for a given quantity (60 milliliters) or the oil at the given temperature to flow through a standard orifice. The right grade of oil, therefore, means oil of the proper viscosity.

THE VISCOSITY INDEX of an oil is based on the slope of the temperature-viscosity curve—or on the rate of change in viscosity of a given oil with a change in temperature, with other conditions remaining unchanged. A low index figure denotes a steep slope of the curve, or a great variation of viscosity with a change in temperature; a higher index figure denotes a flatter slope, or lesser variation of viscosity with identical changes in temperatures. If you are using an oil with a high viscosity index, its viscosity or body will change less when the temperature of the engine increases.

The POUR POINT of an oil is the lowest temperature at which the oil will barely flow from a container. At a temperature below the pour point, oil congeals or solidifies. A low pour point is an essential characteristic of lube oils used in cold weather operations. (NOTE: The pour point is closely related to the viscosity of the oil. In general, an oil of high viscosity will have a higher pour point than an oil of low viscosity.)

The FLASH POINT of an oil is the temperature at which enough vapor is given off to flash when a flame or spark is present. The minimum flash points allowed for Navy lube oils are all above 315° F, and the temperatures of the oils are always far below that under normal operating conditions.

The FIRE POINT of an oil is the temperature at which the oil will continue to burn when ignited.

The AUTO-IGNITION POINT of an oil is the temperature at which the flammable vapors given off from the oil will burn without the application of a spark or flame. For most lubricating oils, this temperature is in the range of 465° F to 815° F.

The NEUTRALIZATION NUMBER of an oil is the measure of the acid content and is defined as the number of milligrams of potassium hydroxide (KOH) required to neutralize one gram of the oil. All petroleum products deteriorate (oxidize) in the presence of air and heat; the products of this oxidation include organic acids, which, if present in sufficient concentration, have harmful effects on alloy bearings at high temperatures, galvanized surfaces, and the demulsibility of the oil with respect to fresh and sea water. This last effect, in turbine installations, may result in the formation of sludge and emulsions too stable to be broken by the means available. An increase in acidity is an indication that the lubricating oil is deteriorating.

The DEMULSIBILITY (or emulsion characteristic) of an oil is its ability to separate cleanly from any water present—an important factor in forced-feed systems. It is especially important to keep water (fresh or salt) out of oils.

The PRECIPITATION NUMBER of an oil is a measure of the amount of solids classified as asphalts or carbon residue contained in the oil. The number is reached by diluting a known amount of oil with naphtha and separating the precipitate by centrifuging—the volume of separated solids equals the precipitation number. The test is a quick means of determining the presence of foreign materials in used oils. An

oil with a high precipitation number may cause trouble in an engine by leaving deposits or by plugging up valves and pumps.

Lubricating Greases

Some lubricating greases are simple mixtures of soaps and lubricating oils. Others are more exotic liquids such as silicones and dibasic acid esters, thickened with metals or inert materials to provide adequate lubrication. Requirements for oxidation inhibition, corrosion prevention, and extreme pressure performance are met by incorporating special additives.

Lubricating greases are supplied in three grades: soft, medium, and hard. The soft greases are used for high speeds and low pressures; the medium greases are used for medium speeds and medium pressures; the hard greases are used for slow speeds and high pressures.

Classification of Greases

Navy specifications have been drawn to cover the several grades of lubricating greases, the grades most common in engineroom use are as follows:

Ball and roller bearing grease, MIL-G-18709.
For general use in ball and roller bearings operating at medium speeds and over a temperature range of 125° F to 200° F and for a short intermittent service at 225° F.

Extreme pressure grease, MIL-G-17740.
Has antirust properties and is suitable for the lubrication of semienclosed gears, or any sliding or rolling metal surfaces where loads may be high and where the equipment may be exposed to salt spray or moisture. It is intended for use through a temperature range of 0° F to 140° F.

Graphite Grease, VV-G-671.
Graphite grease is intended for use in compression grease cups for bearings operating at temperatures not to exceed 150° F.

Grade 1 Soft	For light pressures and high speeds
Grade 2 Medium	For medium pressures and medium speeds
Grade 3 Medium Hard	For high pressures and slow speeds

LUBRICATING SYSTEMS

Main lubricating oil systems on steam-driven ships provide lubrication for the turbine bearing and the reduction gears. The main lubricating oil system generally includes a filling and transfer system, a purifying system, and separate service systems for each propulsion plant. On most ships, each lubricating oil service system includes three positive-displacement lube oil service pumps: (1) a shaft-driven pump, (2) a turbine-driven pump, and (3) a motor-driven pump. The shaft-driven pump, attached to and driven by either the propulsion shaft or the quill shaft of the reduction gear, is used as the main lube oil service pump when the shaft is turning fast enough so that the pump can supply the required lube oil pressure. The turbine-driven pump is used while the ship is getting underway and is then used as standby at normal speeds. The motor-driven pump serves as an emergency pump standby for the other two lube oil service pumps.

Figure 9-2 illustrates the lube oil supply and lube oil drain piping of the service system on the frigates DLG14 and DLG15.

FORCED-FEED LUBRICATION SYSTEMS

The forced-feed lubricating oil systems are used for the lubrication of main engine turbines and reduction gears, turbogenerators, feed pumps and other auxiliary machinery, and in most internal-combustion engines. Each engineroom lube oil system is arranged for independent operation, and generally there is no service connection provided between enginerooms. The main engine lubricating systems include a purifier; whereas the other auxiliary systems must be periodically drained (as the crankcase of an automobile is drained) and replenished with new or purified oil.

The essential parts of a forced lubrication system are as follows:

1. Pumps for delivering the oil to the various parts of the system. If the pump is driven from the unit it serves, additional pumps are provided, where necessary, for supplying oil to the system before the unit is started, during warming up and low speed operation.

2. Oil relief valves are intended primarily to protect the system from excessive pressures that may occur because of a malfunction of an operating part.

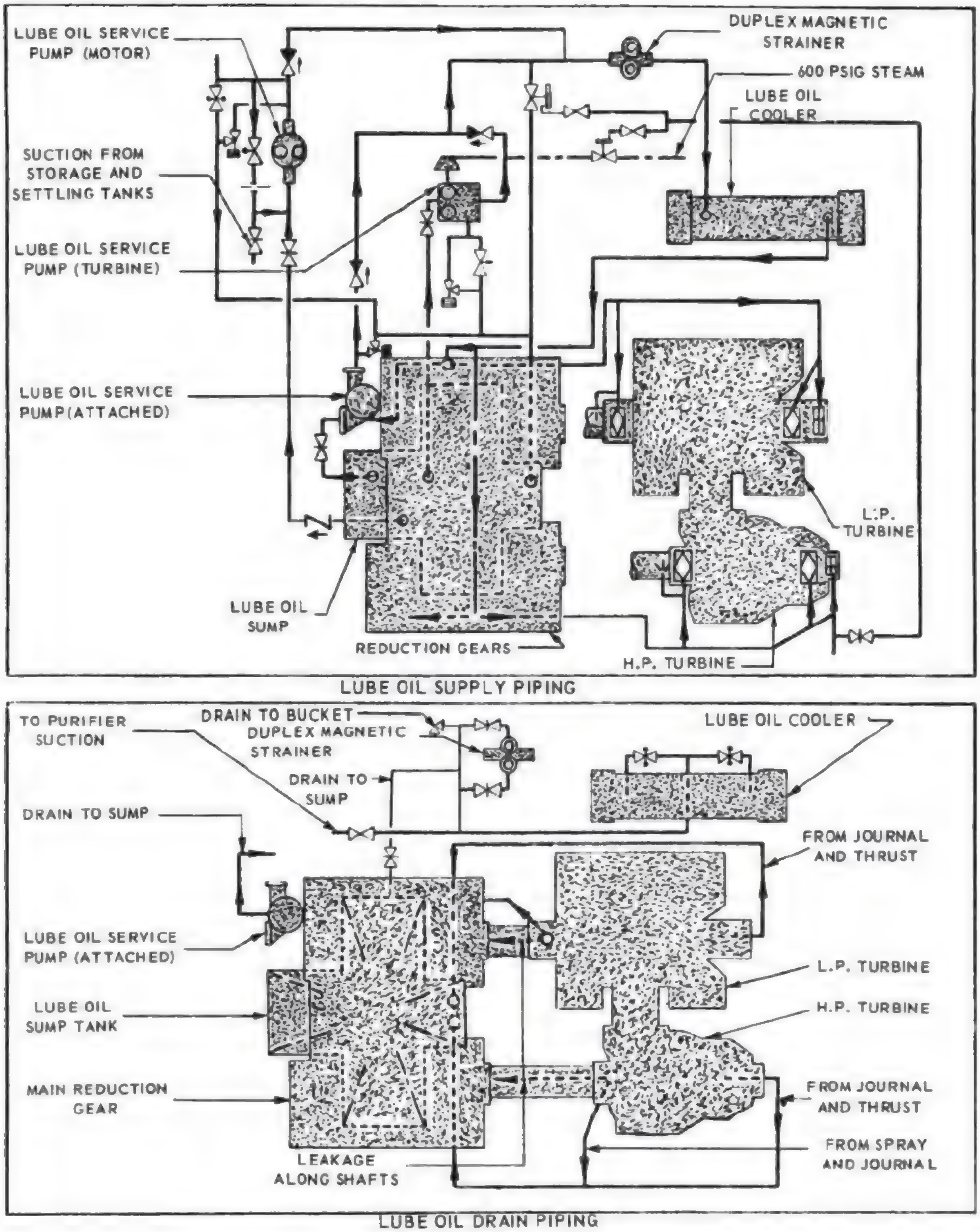

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Figure 9-2.—Lubricating oil service system, DLG 14 and DLG 15.

3. Oil strainers and filters for removing foreign matter from the oil before it enters the bearings and oil sprays.

4. Integral oil cooler heater, through which the oil passes on its way to the system, keeps the oil at the desired temperature.

5. Oil back pressure regulating valve to automatically control the oil pressure at the most remote bearing by bypassing all excess oil back.

6. Piping, gages, thermometers, and other instruments, used to indicate the operating conditions of the system.

7. Oil drain tanks or sump tanks to which the oil is led after having passed through the various bearings and other parts of the system.

8. Oil purifiers, which are used to remove all water and other impurities from the oil that collects in the oil on a daily basis.

9. Oil heaters, which are used to raise the temperature of the oil entering the centrifugal purifier to facilitate removal of water, and other impurities.

10. Oil-settling tanks in which the water and other impurities are removed by special treatment when they have accumulated in the oil.

A forced-feed lubrication system for a main engine and reduction gear installation is illustrated in figure 9-3. Three main lube oil service pumps are provided. Shaft or chain driven pumps installed and operating properly, will supply oil at designed pressure while operating at speeds specified by the manufacturer.

Lube oil standby and emergency pumps are generally provided with an automatic cut in device which starts the pumps when the lubricating oil supply line pressure falls below a certain value. The standby turbine-driven lube oil pump, controlled by a governor, assumes or shares the load when the supply from the attached pump is no longer sufficient to maintain the required pressure. If both the attached and standby pump cannot maintain the system pressure, a pressure sensing switch will then start the emergency motor-driven pump. Usually, at the point of lowest pressure in the lube oil supply line to the bearings, a pressure operated switch WARNING SIGNAL is installed. It is set to operate whenever the lube oil supply falls below a predetermined pressure, thereby giving the throttleman (or operators of other machinery) instant warning of low oil pressure.

The OIL COOLER, through which the oil passes on its way to the lubricated parts, is fitted with thermometers and a bypass (bypasses are not fitted on some new ships). Thermometers register the inlet and outlet oil temperatures; the bypass may be used to bypass the cooler in case of tube failure. Valves are also provided in the cooling water supply and discharge lines to and from the cooler to provide for varying the rate of flow of cooling water, which controls the temperature of the lube oil leaving the cooler. From the cooler, the oil passes to individual bearings through NEEDLE VALVES or, on some ships, internal fixed orifices. These valves regulate the oil flow to the individual bearings. From the bearings, the oil is drained back to the main engine sump. Oil is supplied to the teeth of the reduction gears through SPRAY NOZZLES, after which the oil drains to the main engine sump. A FLOAT GAGE on the sump indicates the oil level. As additional oil is required for the system, it is drained or pumped into the sump from the STORAGE TANK.

Figure 9-4 illustrates a typical main turbine bearing which is lubricated by a forced-feed lube oil service system. Since these bearings are located close to the shaft glands, OIL DEFLECTORS are fitted to prevent leaking gland steam from contaminating the lube oil, and to prevent the oil from escaping.

Oil Purifying and Settling System

The oil purifying and settling functions of the forced-feed system include a centrifugal OIL PURIFIER (discussed later in the chapter), an OIL HEATER for raising the temperature of the oil entering the purifier (to facilitate removal of water), and SETTLING TANKS fitted with steam heating coils.

The oil is normally purified while the lubricating system is in operation. The purifier takes oil from the main sump tank; after it is purified, the oil is discharged back to the same sump. Oil from the smaller forced-feed systems is drained and put into a settling tank, from which the purifier may take a suction when it is not employed in purifying oil of the main system. The purifier is normally operated 12 hours a day for the main system, while underway.

If the oil becomes badly contaminated by water or other impurities, or if it becomes emulsified, the mixture is pumped up to the SETTLING TANKS. Here the oil is heated by

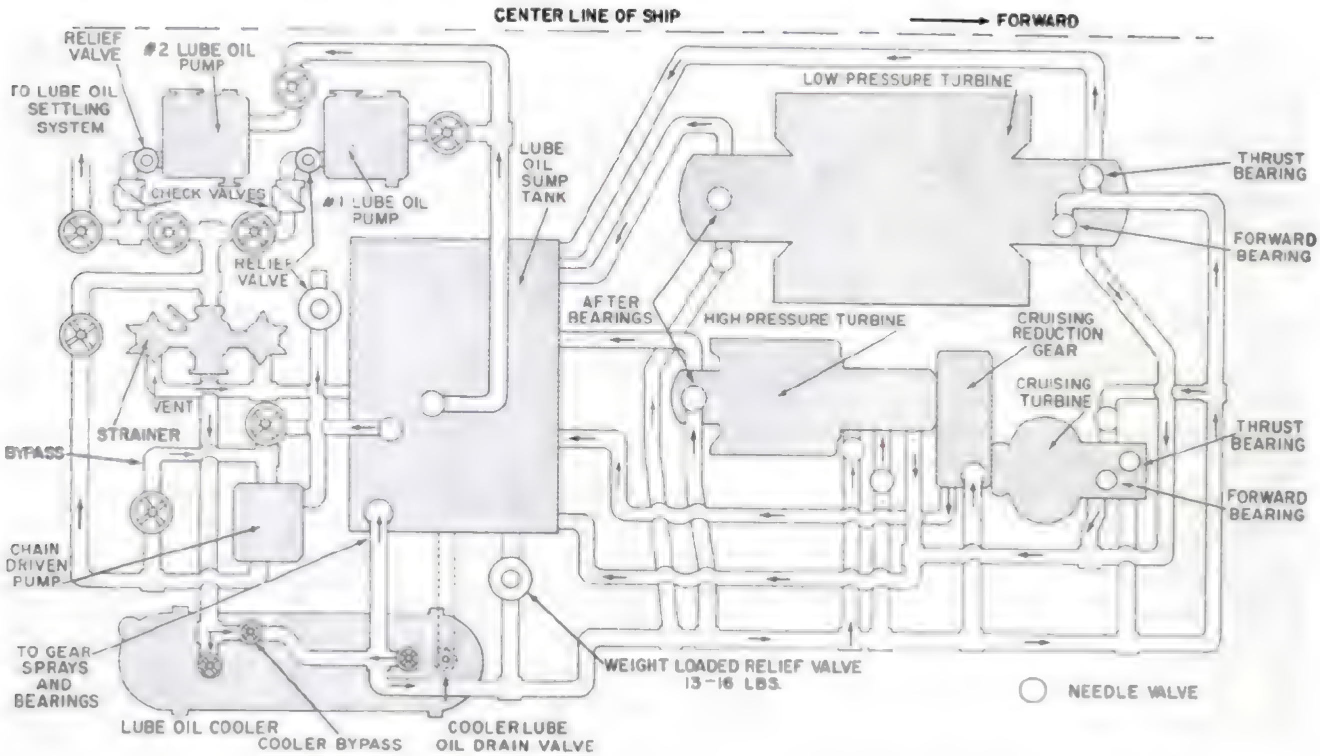

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Figure 9-3.—Diagram of a DD-692 class destroyer forced-feed lubricating system.

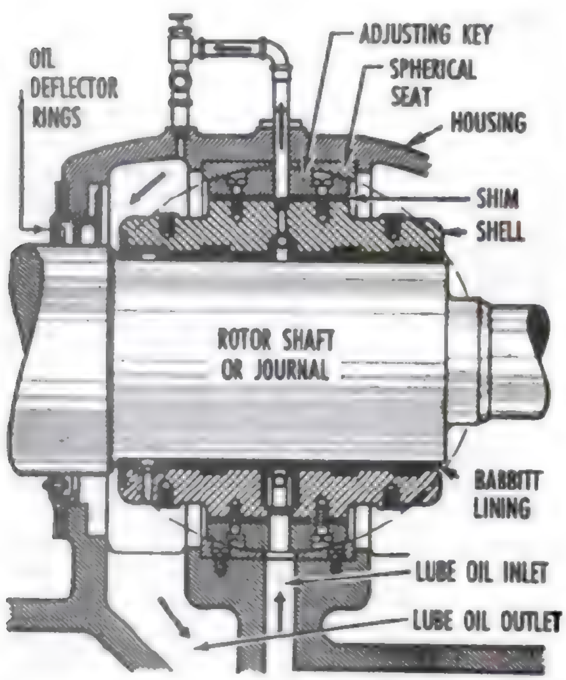
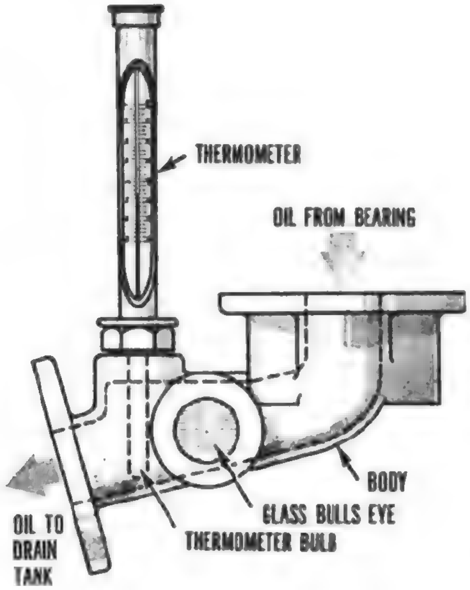


Figure 9-4.—Adjustable spherical-seated bearing lubricated by forced feed. 47.81X

the steam-heated coils. After several hours of heating, the impurities will have settled and can be drawn off through the drains at the bottom of the tanks. The remaining oil is then passed through the purifier and discharged back to the sump. Purification of the main sump oil, by heating and settling, can be done only in port, because all the oil must be pumped out of the main engine sump. This should be done as soon as possible after securing. The reason for this action is to take advantage of the heat accumulated by normal engine operation.

Oil Check Fittings

Various means are provided for maintaining a continuous check on the supply of oil to bearings and on the temperature of oil flowing from the bearings. In modern turbines and reduction gears, a THERMOMETER, and a bull's-eye SIGHT-FLOW fitting are installed in the return line leading from the individual bearing. A combined sight-flow and thermometer fitting (fig. 9-5) is one type normally installed.



47.82X
Figure 9-5.—Combined lube oil sight-flow and thermometer.

A PRESSURE GAGE is also installed outside the gear case—on the header from which oil is fed to the bearings. The thermometers are sometimes of the distant-reading type—with the recording bulbs connected to a dial-type indicator or a temperature monitoring panel.

Oil Pressures

The pressures to be carried at the various parts of the lubrication system differ with the type of installation. Pressure at the service pumps should be such that the pressure at the most remote bearing will be in accordance with the manufacturer's specification. A higher pressure than this will cause the bearings to become flooded and the oil to foam. Pressures shown by the oil gages on the main gage board should indicate the actual pressure at the low pressure alarm connections to the system. Sudden increases in pressure at the pump (usually due to a clogged strainer or pipeline) should prompt immediate checking of oil flow at the bearings. The trouble should be located and corrected at once.

Oil Flow

The flow of oil at the bearing, as seen through the sight-flow glass, must be uniform. Frequent inspections should be made during each watch. If the oil supply is interrupted at any time, the main shaft should be stopped and locked. If the oil temperature rises beyond allowable limits, reduce the shaft speed and notify the bridge.

Oil Temperatures

Bearing temperatures depend on the viscosity of the oil being used, design of the bearing, rpm, and clearances. The manufacturer's technical manual for a unit gives the correct temperatures of lube oil flowing from the bearings. The temperature rise of oil passing through the bearings should not exceed 50° F (difference between discharge of lube oil cooler and the temperature leaving the bearing), even though the maximum allowable temperature is not exceeded. Investigate the cause of any rising temperature that fails to level off, no matter how slowly it is rising.

Since friction loss in a journal bearing is directly proportional to the oil viscosity, and the viscosity depends upon the temperature, the oil leaving the cooler should be between 120° and 130° F. The efficiency of double reduction gears, for example, will be decreased appreciably at cruising speeds, if operated at temperatures lower than those prescribed.

Take PRECAUTIONS WITH THE THERMOMETERS. Make certain that the bulbs are sufficiently immersed in the oil streams to give an accurate reading. In many cases, the thermometers give only the average temperature in the bearing reservoir. Checks on temperature should, therefore, be periodically made by feeling the cap and by inspecting the sight glasses to ensure that there is a flow of oil.

The OIL COOLERS should be put into operation when the temperature of the oil from the cooler reaches 120° F. The temperature from the cooler should be carried at 120° to 130° F. When the system has more than one cooler, the coolers should be used alternately. (The operating principles of the lube oil cooler are discussed in the preceding chapter.)

Oil Purity

Lubricating oils may be kept in service for long periods of time, provided the purity of the oil is maintained at the required standard. The simple fact is that lubricating oil does not wear out, although it can become unfit for use

when it is robbed of its lubricating properties by the presence of water, sand, sludge, fine metallic particles, acid, and other contaminants.

Proper care of lubricating oil requires, then, that the oil be kept as free from contamination as possible and that, once contaminated, the oil must be purified before it can be used again.

Strainers are used in many lubricating systems to prevent the passage of grit, scale, dirt, and other foreign matter. Duplex strainers are used in lubricating systems in which an uninterrupted flow of lubricating oil must be maintained; the flow may be diverted from one strainer basket to the other while one is being cleaned. If pieces of metal are found, determine the character of the metal. Later ships have strainer magnets installed to remove ferrous (iron) particles from the oil. Bits of brass or babbitt metal indicate that there is a damaged, or wiped, bearing in the system, or that the bearing metal is breaking up. If the metal has the appearance of rust, it indicates that corrosion is occurring in the system. Pieces of metal rust will scratch the bearing or mar a thrust shoe. A sudden rise in bearing temperature, followed by a return to normal, usually indicates that some foreign substance reached the bearing, scratched it, and was then washed out by the oil supply. The oil strainers should be removed and cleaned during each watch.

The use of strainers does not solve the problem of water contamination of lubricating oil. Even a very small amount of water in lubricating oil can be extremely damaging to machinery, piping, valves, and other equipment. Water in lubricating oil can cause widespread pitting and corrosion; also, by increasing the frictional resistance, water can cause the oil film to break down prematurely. Every effort must be made to prevent the entry of water into any lubricating system.

Water may actually cause corrosion in the entire system, particularly in those parts which are not covered with oil at all times. Condensation of moisture, which promotes rusting on exposed surfaces such as gear casings, upper portions of drain tanks, etc. should be prevented by eliminating factors which tend to reduce the temperature of the surfaces. All unprotected escape hatches in the vicinity of gear casings must be kept secured at all times when the temperature of the outside air is less than 70°F, except when engines are secured. Air from ventilation ducts should never blow directly or indirectly on the gear casing. When coming to anchor, or securing main propulsion machinery, circulate oil through the system for at least an hour to minimize the effects of an unavoidable amount of fresh-water condensation.

Water enters the lubrication system at the following principal points:

1. Leaky tubes or joints in the oil coolers.
2. Steam-sealed glands or turbines (sometimes because of clogged drain).
3. Vents on tanks and gear casings (as atmospheric moisture, subsequently condensed).
4. Leaks in drain or sump tanks located in bilges.

Lube oil may lose its lubricating qualities if it is contaminated, but if the impurities and water are removed as soon as their presence is noted, the oil can be used over and over indefinitely. To ensure that the oil is kept free of all foreign matter, a sample of lube oil should be drawn from the auxiliary machinery sumps about once a week. Allow this sample to settle and examine for contamination. If the lube oil shows any contamination, drain the oil system of the particular piece of auxiliary machinery, and replenish the system with clean lube oil. The contaminated oil should be placed into one of the settling tanks and purified at some later date.

CENTRIFUGAL PURIFIERS (centrifuges) are used to purify the lube oils. Because of the importance of this purifier, and because it is employed for the purification of lube oil used in other than forced-feed systems, it is treated somewhat fully further on in this chapter. Generally, the oil must be heated to higher than operating temperature before being run through the centrifuge. This results in a greater degree of purification.

GRAVITY-FEED LUBRICATION SYSTEMS

There are two types of gravity-feed lubricating systems—the gravity force feed and the straight gravity feed. The straight gravity-feed system is further differentiated as being either a DRIP-FEED or a WICK-FEED system. None of these systems will be found to any great extent on the modern naval ships.

SELF-OILING SPRING BEARINGS

Main shaft spring bearings on the propulsion shaft are lubricated by a self-oiling system. Most of these bearings are ring-oiled, though some are chain-oiled. You must know how to ensure continuous correct lubrication of these important units.

Ring-Oiled Spring Bearings

The lubrication system for the ring-oiled bearings consists of an OIL SUMP below the bearing journal, and brass OILER RINGS which are hung loosely over the journal and lower half of the bearing. These rings are immersed in the oil and carry a continuous supply of oil over the journal as the rings are dragged around by the rotation of the shaft. The rings must be finished smoothly and fit properly in the guides in the upper half of the bearing shell to prevent hanging and failure to rotate evenly. The upper half of the bearing is cut away in the middle to accommodate the oiler rings. A hinged ACCESS COVER in the upper half of the bearing housing permits inspection of the journal and oiler rings. The OIL DEFLECTOR RINGS, secured to the shaft, keep the oil within the bearing space.

Care of Spring Bearing Oil

The frequency of changing the oil and cleaning the oil sumps depends upon the service and the mechanism. If the oil doesn't become contaminated by impurities, it can be used for an extended period before the lubricating qualities are reduced. Regardless of condition, the oil should be drained once a quarter and run through the purifier. Whenever the oil is renewed, the sump should be thoroughly cleaned. Be sure to keep inspection openings in operating condition, and closed when not in use.

Samples of the oil in the sump should be examined after each extended run, and after 10 days of periodic service. If the oil shows an increase in viscosity, discoloration, or formation of sludge deposits in the reservoir, immediate renewal is necessary. When underway, the oil level and bearing operations must be inspected and logged hourly.

GREASE LUBRICATION SYSTEMS

Grease lubrication is employed in many locations where the retention of lube oil at the bearing surface would otherwise be difficult. The grease is applied either through the use of grease cups or through pressure fittings, such as the Zerk type.

Grease Cup Lubrication

Whereas dirt in lube oil will generally settle out, dirt in grease remains mixed with grease and becomes abrasive. For this reason, particular care must be taken to prevent contamination, especially where grease cups are used. Before opening the container, all dirt should be carefully removed from the exterior. No dirt must be allowed to enter either the opening or the grease cups. The cups should be frequently emptied, cleaned, and refilled with fresh grease.

Pressure Greasing

Pressure fittings form a convenient means of lubricating numerous low-speed, lightly loaded, or widely separated bearings. They are not, however, satisfactory for use on electric generators and motors because of the danger of forcing grease out of the bearing and onto windings. These fittings are similar to those on an automobile, where grease guns are employed for lubrication.

Before applying the grease gun, the pressure fittings should be wiped clean. The gun tip, too, must be clean. The pressure should be applied until grease comes out around the edges of the bearing. In bearings fitted with felt or other seals, care must be taken to avoid breaking the seals by overpressure. Excessive pressure in the lubrication of needle-type roller bearings may unseat the needles.

BALL AND ROLLER BEARING LUBRICATION

The oil or grease employed for the lubrication of ball and roller bearings (known jointly as ROLLER CONTACT BEARINGS) provides a lubricating film between the balls and rollers and the retainers, and between ends of the rollers and the races; dissipates heat caused by friction; prevents corrosion of the highly polished parts; and aids in excluding dirt, water, and other foreign matter. The lubricant specified for each

machine should be used, and excessive lubrication should be avoided.

Oil Lubrication

Where ball or roller bearings are oil lubricated, the lube oil, as speeds increase, begins churning and produces heat. The quantity of oil must, therefore, be reduced accordingly, until at very high speeds only a mist of oil is desirable. It is common practice to fill the bearing housing to a point between the center of the lower ball and the lowest point of the inner ring, depending upon the speed of operation. DRAINS are generally installed to prevent the oil from rising above this point; SIGHT INDICATORS are also provided. For extremely high speeds, the drip-feed or wick-feed gravity lubrication is sometimes used.

Grease Lubrication

To apply grease to ball and roller bearings, proceed as follows:

1. Remove the relief plug at the bottom of the bearing closure and free a hole through the cavity.
2. With the mechanism running, turn down the grease cup slowly until grease begins to push through the relief plug hole.
3. Leave the hole open for 10 to 15 minutes, then free the hole again with a clean rod or knife, and replace the plug.
4. If excessive grease appears when the plug is removed, remove the cover and clean out excessive grease. Add sufficient grease, if necessary, to the bearing closure to make it about 1/3 to 1/2 full. This procedure should be followed after new bearings are installed.

Where a relief pipe is fitted to the bearing closure or grease sump, and the closure is not accessible, the relief pipe should be removed (if possible) and thoroughly cleaned. A stiff, clean wire should be inserted through the pipe, to free an opening through the grease in the sump, before attempting to replenish the lubricant in the bearing.

After relubricating with the relief plug off the relief pipe, and with the motor running, leave the plug open for 10 to 15 minutes, occasionally loosening the excess grease in the pipe with the stiff wire. Then remove the relief pipe and free it of excess grease, attach it to the closure, and place the plug in the end of the relief pipe.

LUBE OIL PURIFICATION

In the forced-feed lubrication systems on modern naval ships, if the purity of the oil remains intact, the oil may be kept in service for a long period of time. LUBE OIL DOES NOT WEAR OUT; it is merely robbed of its lubricating properties by foreign substances. In other words, improper performance of a correct oil is not due to internal change, but to contamination or to the formation of sludge. No one would ever willfully pour into the lubrication system of his machine a mixture of oil, water, sand, fine metallic particles, sludge, and acid. Yet lubricating systems do contain mixtures of this nature, when preventive measures are not taken. The centrifugal oil purifier is employed on all naval ships to remove the water and other foreign matter from the lube oil. Water is the greatest source of contamination.

Contamination must be removed or the oil will not meet lubrication requirements. Dirt, sludge, and other contaminants will act as abrasives to score and scratch the rubbing metal surfaces within engines, generators, pumps, and blowers. Contaminants interfere with the ability of the oil to maintain a good lubricating film between metal surfaces.

Several different devices are used to keep the oil as clean as possible. Each device is designed to remove certain kinds of contamination and it takes several types of devices in a lubricating system to keep oil in a usable condition. Strainers, filters, settling tanks, and centrifugal purifiers are the devices used to free oil of contamination. Strainers and filters will not be discussed in this chapter—settling tanks and purifiers will be discussed, with emphasis on purifiers.

SETTLING TANKS

Shipboard lubricating systems include settling tanks which permit used oil to stand while water and other impurities settle out. Settling is due to force of gravity. A number of layers of contamination may form, the number of layers formed depending upon the difference in specific gravity of the various substances. For example, there might be a layer of metal particles on the bottom, then a layer of sludge, then a layer of water, and then the clean oil.

Lubricating oil piping is generally arranged to permit two methods of purification: batch purification and continuous purification. In the batch process, usually done while the ship is

in port, the lubricating oil is transferred from the sump to a settling tank by means of a purifier or a transfer pump. (After the oil is heated and allowed to settle for several hours, water as well as other impurities are removed from the settling tanks. The oil is then centrifuged and returned to the sump from which it was taken.)

CENTRIFUGAL PURIFICATION

While a ship is at sea or when time does not permit batch purification in the settling tanks the continuous purification process is used. Centrifugal purifiers are also used in this process. The purifier takes the oil from the main sump in a continuous cycle. Before entering the purifier, the oil is heated to facilitate easier removal of the impurities.

Detailed instructions on construction, operation, and maintenance of purifiers are furnished by the 3-M System and the manufacturers. The instructions should be carefully studied and followed by the personnel who are responsible for operation and maintenance of purifiers. The following general information is provided to familiarize you with the methods of purification and the purposes and principles of operation of purifiers.

PRINCIPLES OF PURIFIER OPERATION

In the purification process, a purifier may be used to remove water and sediment from oil or to remove sediment only. When water is involved in the purification process, the purifier is called a SEPARATOR. When the principal item of contamination is sediment, the purifier is used as a CLARIFIER. When used to purify lubricating oil, a purifier may be used as either a separator or a clarifier. Whether a purifier is used as a separator or a clarifier depends upon the moisture content of the oil to be purified.

If an oil contains no moisture, it needs only to be clarified, since the solids will be deposited in the bowl, and the oil will be discharged in a pure state. If, however, the oil contains some moisture, the continued feeding of "wet" oil to the bowl results eventually in a bowl filled with water, and from then on the centrifuge is not separating any water from the oil. Even before the bowl is completely filled with water, the presence of a layer of water in the bowl reduces the depth of the oil layer. As a result, the incoming oil passes through the bowl at a very high velocity.

This higher velocity means that the liquid is under centrifugal force for a shorter time, and the separation of water from the oil is, therefore, not so complete as it would be if the bowl were without the water layer, or if the water layer were a shallow one. Because of this, the centrifuge should not be operated as a clarifier unless the oil contains very little or no water. A small amount of water can be satisfactorily accumulated, together with the solids, to be drained out when the bowl is stopped for cleaning. However, if there is any appreciable amount of water in the oil, the bowl should be operated as a separator.

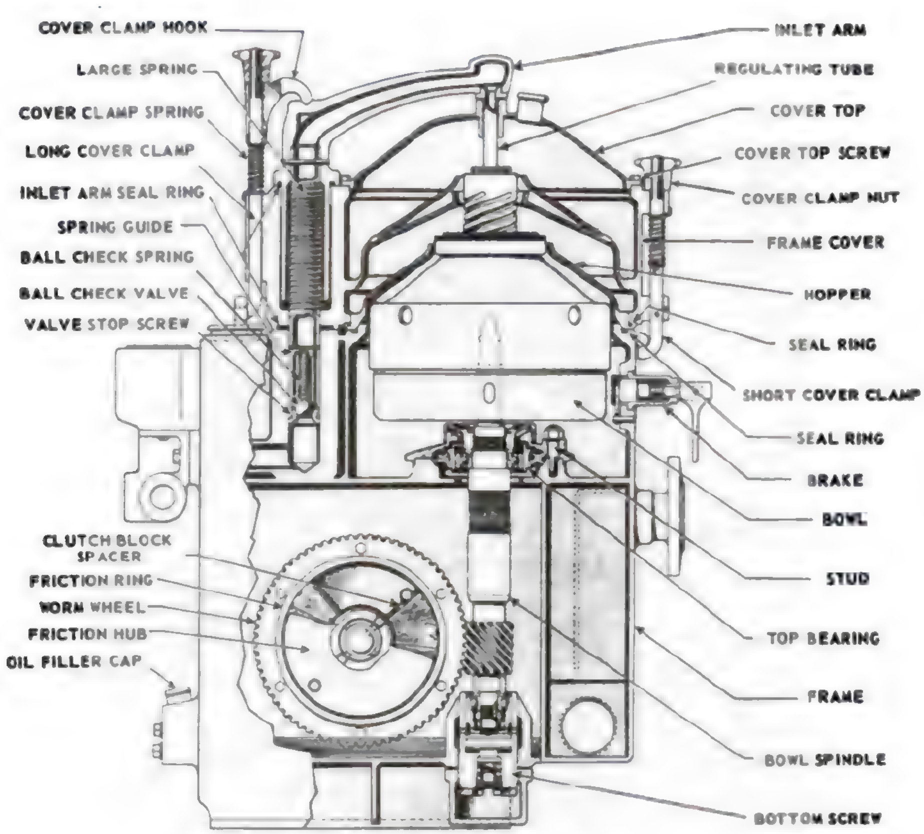
TYPES OF CENTRIFUGAL PURIFIERS

There are two types of purifiers used in Navy installations. Both types operate on the same principle. The principal difference in the two types of purifiers is in the design of the rotating units. In one type the rotating element is a bowl-like container which encases a stack of disks and in the other type the rotating element is a hollow, tubular rotor; thus, they are known as the DISK-TYPE PURIFIER and the TUBULAR-TYPE PURIFIER.

A sectional view of a disk type centrifugal purifier is shown in figure 9-6. The bowl is mounted on the upper end of the vertical bowl spindle, which is driven by means of a worm wheel and friction clutch assembly. A radial thrust bearing is provided at the lower end of the bowl spindle to carry the weight of the bowl spindle and to absorb any thrust created by the driving action.

The parts of a disk-type bowl are shown in figure 9-7. The flow of oil, through the bowl and additional parts, is shown in figure 9-8.

Contaminated oil enters the top of the revolving bowl through the regulating tube. The oil then passes down the inside of the tubular shaft and out at the bottom into the stack of disks. As the dirty oil flows up through the distribution holes in the disks, the high centrifugal force exerted by the revolving bowl causes the dirt, sludge, and water to move outward and the purified oil inward toward the tubular shaft. The disks divide the space within the bowl into many separate narrow passages or



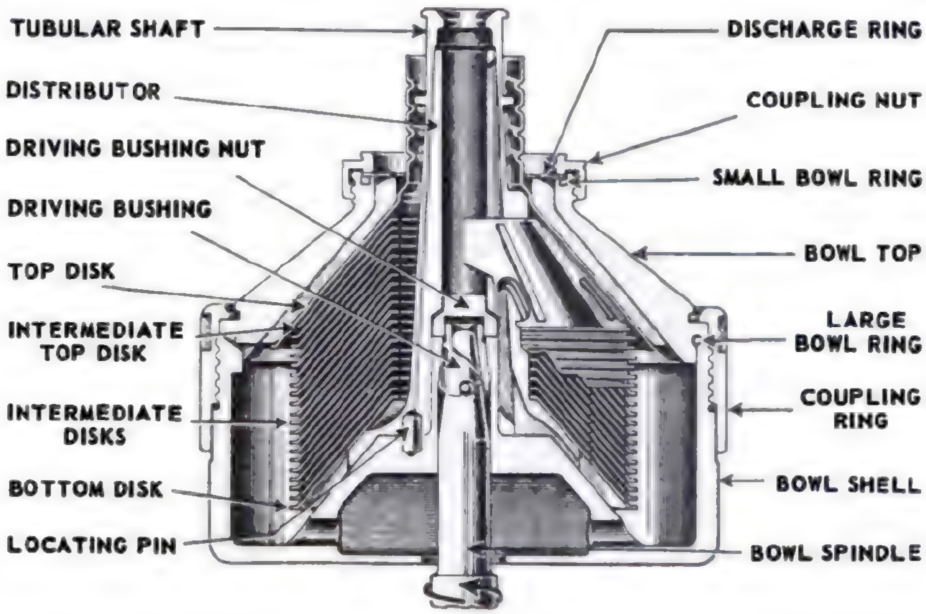
47.83
Figure 9-6.—Disk-type centrifugal purifier.

spaces. The liquid confined within each passage is restricted so that it can only flow along that passage. This arrangement prevents excess agitation of the liquid as it passes through the bowl and creates shallow settling distances between the disks.

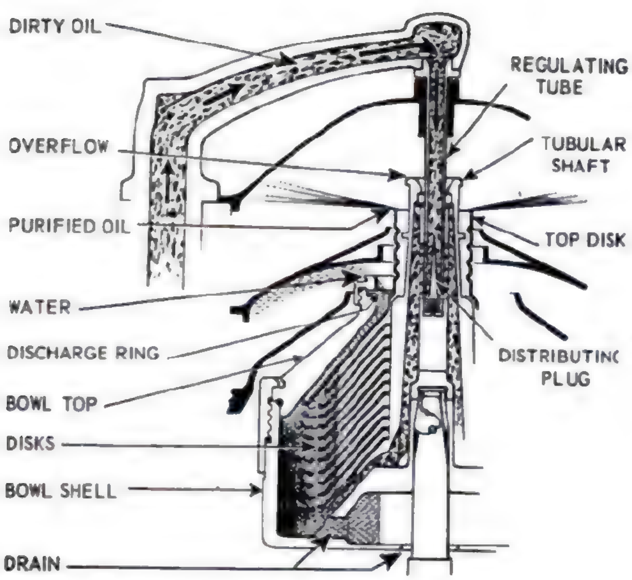
Most of the dirt and sludge remains in the bowl and collects in a more or less uniform layer on the inside vertical surface of the bowl shell. Any water, along with some dirt and sludge, separated from the oil, is discharged through the discharge ring at the top of the bowl. The purified oil flows inward and upward through the disks, discharging from the neck of the top disk (fig. 9-8.)

A cross section of a tubular-type centrifugal purifier is shown in figure 9-9. This type of purifier consists essentially of a hollow rotor or bowl which rotates at high speeds. The rotor has an opening in the bottom to allow the dirty lube oil to enter and two sets of openings at the top to allow the oil and water (separator) or the oil by itself (clarifier) to discharge (see insert, fig. 9-9). The bowl, or hollow rotor, of the purifier is connected by a coupling unit to a spindle which is suspended from a ball bearing assembly. The bowl is belt-driven by an electric motor mounted on the frame of the purifier.

The lower end of the bowl extends into a flexibly mounted guide bushing. The assembly, of which the bushing is a part, restrains movement of the bottom of the bowl, but allows sufficient movement so that the bowl can center itself about its center of rotation when the purifier is in operation. Inside the bowl is a device consisting essentially of three flat plates equally spaced radially. This device is commonly referred to as the three-wing device, or just the three-wing. The three-wing rotates



47.84
Figure 9-7.—Parts of a disk-type purifier bowl.



47.84
Figure 9-8.—Path of contaminated oil through disk-type purifier bowl (De Laval).

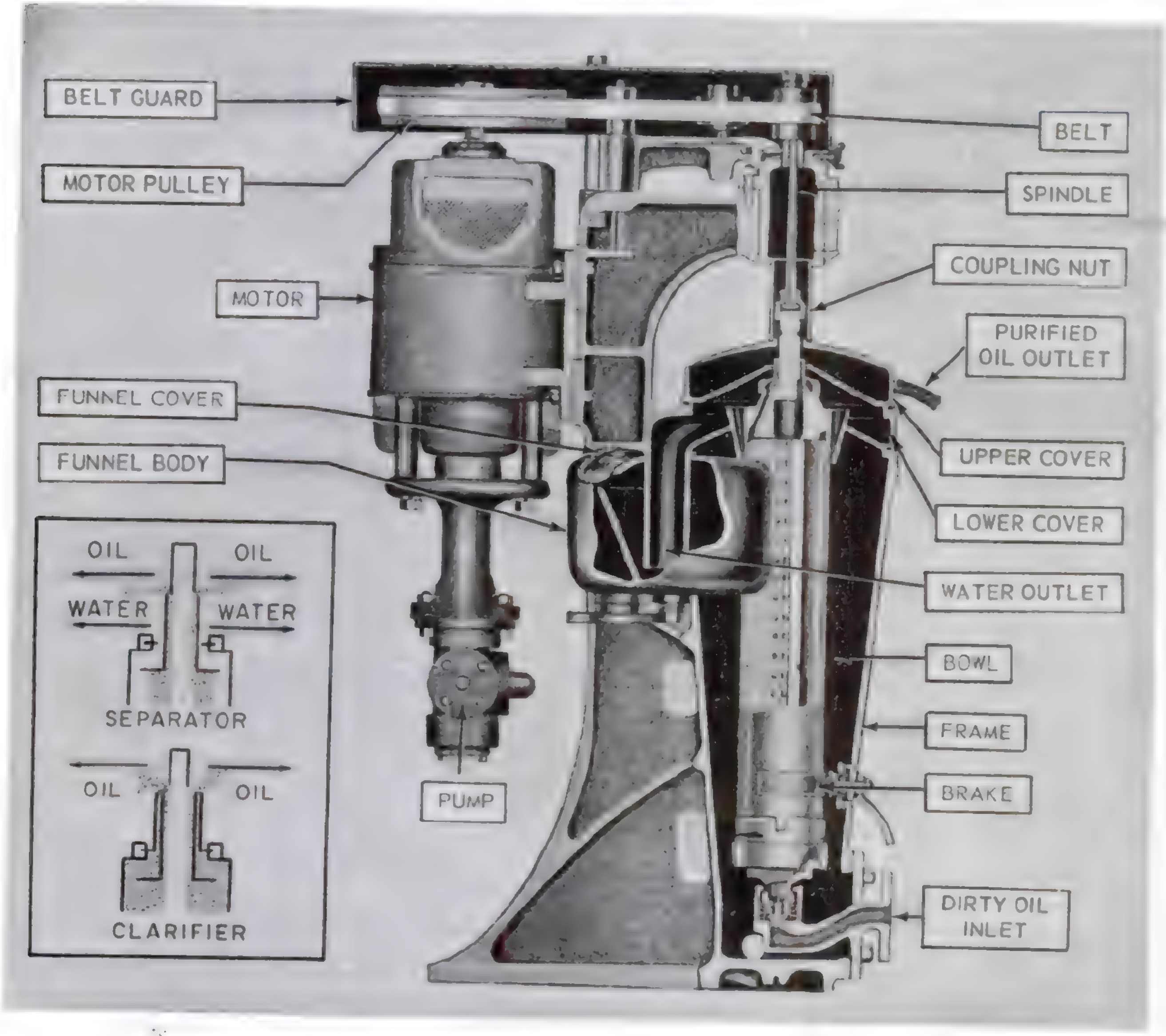
with the bowl and forces the liquid in the bowl to rotate at the same speed as the bowl. The liquid to be centrifuged is fed into the bottom of the bowl through the feed nozzle, under pressure, so that the liquid jets into the bowl in a stream.

When the purifier is used as a lube oil clarifier, the three-wing has a cone on the bottom, against which the feed jet strikes in order to bring the liquid up to bowl speed smoothly without making an emulsion. Both types of three-wing devices are shown in figure 9-10.

The process of separation is basically the same in the tubular-type purifier as in the disk-type purifier. In both types, the separated oil assumes the innermost position and the separated water moves outward. Both liquids are discharged separately from the bowls, and the solids separated from the liquid are retained in the bowl (fig. 9-11).

GENERAL NOTES ON PURIFIER OPERATIONS

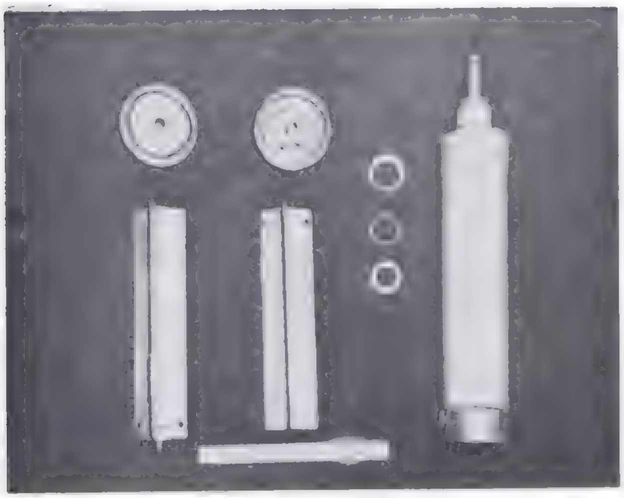
The specific details for operating a given purifier should be obtained from the appropriate



47.86
Figure 9-9. — Tubular-type centrifugal purifier.

instructions provided with the unit. Information provided here is, in general, applicable to both types of purifiers.

For maximum efficiency, purifiers should be operated at maximum designed speed and rated capacity. Since turbine oils are always contaminated with water of condensation, the purifier bowls should be operated as separators and not as clarifiers. An exception to operating a purifier at designed rated capacity is when a unit is used as a separator of 9000 series (compounded or additive-type-heavy-duty lube oils) detergent oil. Some engine installations using oils of the 9000 series are exposed to large quantities of water. If the oil becomes contaminated with water, the oil has a tendency to emulsify. The tendency to emulsify is most pronounced when the oil is new, and gradually decreases during the first 50 to 75 hours of engine operation. When an emulsion appears, the purifier should be reduced to approximately 80 per cent of the rated capacity and operation



47.87
Figure 9-10.—Parts of a tubular-type purifier bowl.

continued as long as an appreciable amount of free water discharges along with the emulsion.

When a purifier is operated as a separator, PRIMING OF THE BOWL with fresh water is essential before any oil is admitted to the purifier. The water serves to seal the bowl and to create an initial equilibrium of liquid layers. If the bowl is not primed, the oil will be lost through the water discharge ports.

There are several FACTORS WHICH INFLUENCE PURIFIER OPERATION. The time required for purification and the output of a purifier depend upon such factors as the viscosity of the oil, the pressure applied to the oil, the size of the sediment particles, the difference in the specific gravity of the oil and the substances which contaminate the oil, and the tendency of the oil to emulsify.

The viscosity of the oil determines to a great extent the length of time required to purify lube oil. The more viscous the oil, the longer the time required to purify it to a given

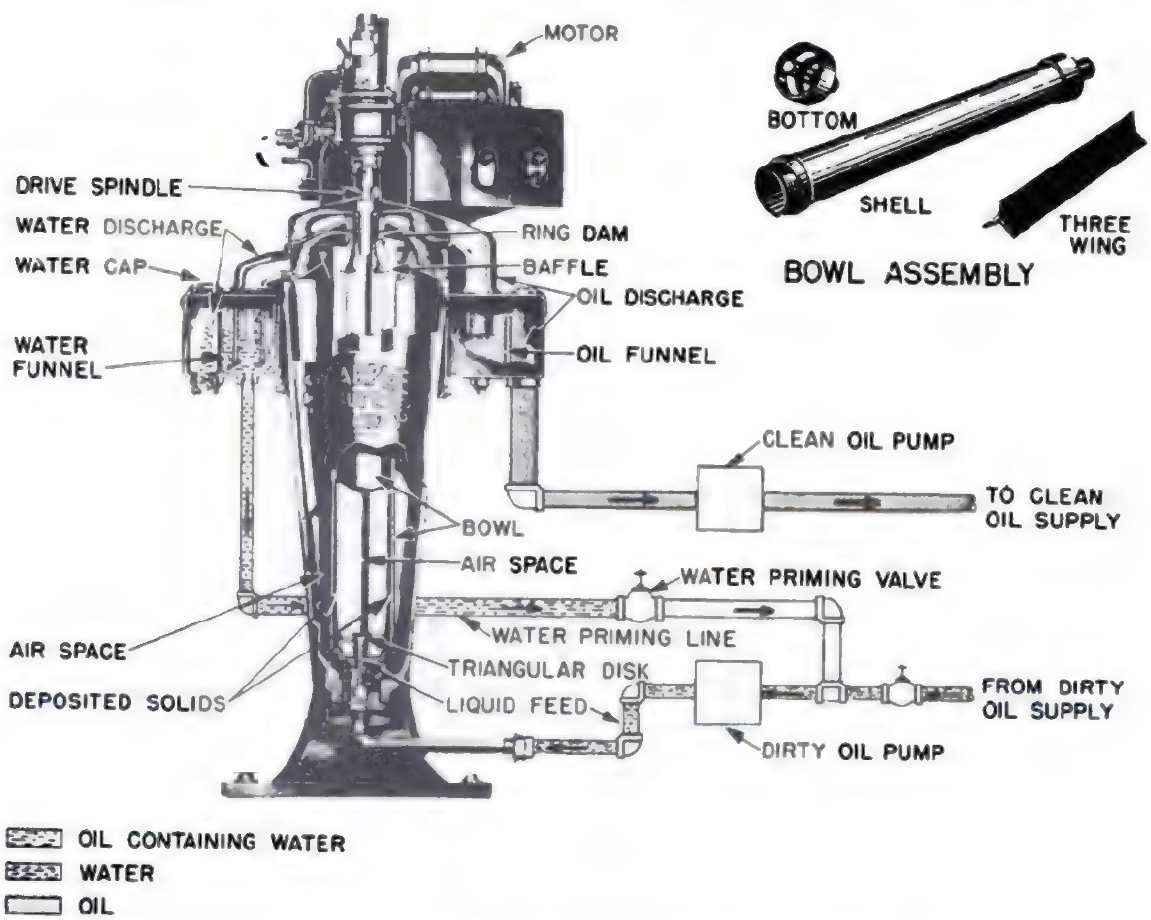


Figure 9-11.—Path of contaminated oil through a bowl type purifier (Sharples). 47.88

degree of purity. Decreasing the viscosity of the oil by heating is one of the most effective methods of facilitating purification.

Even though certain oils may be satisfactorily purified at operating temperatures, a greater degree of purification will generally result by heating the oil to a higher temperature. To accomplish this, the oil is passed through a heater where the proper temperature is obtained before the oil enters the purifier bowl.

Oils used in Naval installations may be heated to specified temperatures without adverse effects, but prolonged heating at higher temperatures is not recommended because of the tendency of such oils to oxidize. Oxidation results in rapid deterioration. In general, oil should be heated sufficiently to produce a viscosity of approximately 90 seconds, Saybolt Universal (90 SSU).

Pressure should not be increased above normal in order to force a high-viscosity oil through the purifier. Instead, viscosity should be decreased by heating the oil. The use of pressure in excess of that normally used to force oil through the purifier will result merely in less efficient purification. On the other hand, a reduction in the pressure at which the oil is forced into the purifier will increase the length of time the oil is under the influence of centrifugal force, and therefore will tend to improve results.

If the oil discharged from a purifier is to be free of water, dirt, and sludge, and the water discharged from the bowl is not to be mixed with oil, the PROPER SIZE DISCHARGE RING (RING DAM) must be used. The size of the discharge ring to be used depends upon the specific gravity of the oil being purified. All discharge rings have the same outside diameter, but have inside diameters of different sizes. Ring sizes are indicated by even numbers and the smaller the number, the smaller the ring size. The size, in millimeters, of the inside diameter is stamped on each ring. Sizes vary by two-millimeter steps. Charts, provided in manufacturer's technical manuals, specify the proper ring size to be used with an oil of a given specific gravity. Generally, the size ring indicated on a chart will produce satisfactory results. However, if the recommended ring fails to produce satisfactory purification, it will be necessary to determine the correct size by trial and error. In general, the most satisfactory purification of the oil is obtained when the ring used is of the largest size possible without causing loss of oil with the discharged water.

MAINTENANCE OF PURIFIERS

Proper care of an oil purifier requires that the bowl be cleaned frequently and all sediment carefully removed. The frequency of cleaning depends upon the amount of foreign matter in the oil to be purified. If the amount of foreign matter in an oil is not known, the machine should be shut down for examination and cleaning once during each watch, or more often if necessary. The amount of sediment found in the bowl at this time will give an indication as to how long the purifier may be operated between cleanings. The bowl should be thoroughly cleaned each time lube oil is run through for batch purification from the settling tank.

Periodic tests should be made to ensure that the purifier is working properly. Tests should be made at intervals of about 30 minutes when the oil in the system is being purified by the batch process. When the continuous process of purification is used, tests should be made once a watch. If these tests show oil free of water and sediment, the purifier may be operated at the rate of 12 hours per day and cleaned once a watch.

The general efficiency of the purifier may be determined by observing the clarity of the purified oil and the amount of oil in the separated water.

Purifiers should be tested and inspected in accordance with the 3-M Planned Maintenance System requirements.

CHAPTER 10

ENGINEROOM OPERATING PROCEDURES

The information in this chapter deals primarily with the Personnel Qualification Standards (PQS), Engineering Operational Sequencing Systems (EOSS), Watchstanding, and Operating Procedures for steam-driven propulsion machinery fitted with reduction gears.

Although the Personnel Qualification Standards and Engineering Operational Sequencing System are new training programs, they overlap the present watchstanding and operating procedures.

The four phases of Navy training mentioned above are closely allied and contribute to the development of highly trained and fully qualified individuals who man the ships of our modern Navy. In addition to studying the material in this chapter, you must become familiar with those manufacturer's technical manuals which apply specifically to each main turbine and auxiliary unit installed on your ship, the standard operating procedures, and specific orders issued by your engineering officer.

PERSONNEL QUALIFICATION STANDARDS

The increasing need for greater technical know-how within our Navy makes proper qualification of personnel a matter of importance. Every man wants to do a good job and will perform that job well, if he is properly trained.

The personnel qualification standards are the tools that will let each man know:

His job
His place in the ship
His responsibilities to his shipmates
And his purpose in fighting

The personnel qualification standards describe the knowledge and skills the individual must have to correctly perform his duties. It places the responsibility for learning squarely on the shoulders of the learner, and encourages self-achievement. By providing a convenient record of accomplishment, it provides a means whereby a man can check his speed and manner of performance.

The discussion of PQS in this chapter is intended to give you a general idea of how PQS will help one understand how they are used.

The four main sub-divisions in the qualification standards are:

100 Series—THEORY
200 Series—SYSTEMS
300 Series—WATCHSTATIONS
400 Series—QUALIFICATION CARDS

THEORY

The theory section of the qualification standards covers the basic information needed for dealing with the machinery and duties to be performed. Each portion of the theory section specifies the reference books to be studied. Normally, you would have acquired these fundamentals during the school phase of your training. If you have not been to school, the requirements are outlined and referenced to aid you in a self-study program.

SYSTEMS

In the systems portion of the PQS, the machinery is broken down into functional sections as the basic building blocks in the learning process. This equipment can be studied, inspected, and discussed to the desired extent in a reasonable period of time. For a complete understanding, all functional parts must be considered in the study of the system.

2214 MAIN FEED RECIRCULATION SYSTEM

2214.1 Explain the function or the functions of the MAIN FEED RECIRCULATION SYSTEM as stated in Manufacturer's Technical Manual and Main Feed Pump Control Manual, NAVSHIPS Technical Manual 351-0654 and 351-0649.

.11 Draw a one line schematic diagram of this system from memory using appropriate symbols and showing all componentslisted in 2214.2 for use during the rest of this discussion.

.12 Refer to a standard print of this system during the rest of this discussion.

2214.2 SYSTEM COMPONENTS - GENERAL

Discuss the designated items for each component listed below:

A. Explain the function or the functions of the component in terms of what it does for the system.
B. Describe the functional location of the component with respect to its position in the system and the reason(s) for its location in this position.
C. Show or describe the actual physical location of this component.
D. Describe the sources of power.
E. List or describe the mode(s) of operation.
F. Discuss the protection provided by this component.
G. Describe the "fail" position of the component on loss of control signal and the reason(s) it fails in this position.

		A	B	C	D	E	F	G
.21	Flow transmitter	X	X	X	X			
.22	Recirculation control valve and positioner	X	X	X	X	X	X	X

2214.3 COMPONENT PARTS

A. There are no component parts in this system to be discussed.

2214.4 PRINCIPLES OF OPERATION

Demonstrate an understanding of the internal operation of this system by describing:

.41 The flow path of feed water from the main feed pump discharge to the suction side.

.42 How a minimum flow of feed water is maintained through each main feed pump.

104.75.4

Figure 10-1.—Personnel Qualification Standards.

2214.5 MAJOR PARAMETERS

A. Show or describe the physical location at which the parameter is displayed for monitoring.

.51 Control air signal — A / X

2214.6 SYSTEM INTERRELATIONS

A. Describe the effect on this system due to the following:
1. Loss of ACC air pressure
2. Variation in feed pump speed

B. Describe the effects on the following systems due to the operation of this system:
1. Main Feed System
2. Deaerating feed tank

2214.7 SAFETY PRECAUTIONS

A. There are no safety precautions unique to this system.

104.75.5

Figure 10-1.—Personnel Qualification Standards—continued.

The pattern to the numbers to the right of the decimal point is in the 200 series as illustrated in figure 10-1:

.1 At this point, you will always be asked to explain the function of the systems.

.11 Here you will be asked to draw a simplified version of the system from memory.

.12 Refer to a standard print. (You will be asked to use either the simplified version or the standard print as a reference while studying the system.)

.2 SYSTEM COMPONENTS—GENERAL

The system's components are listed in this section and you will be told what you must learn about each component. Note that the definition of COMPONENT is not restricted to a single piece of machinery with a single federal stock number. It may be either a single bearing or a governor assembly.

.3 COMPONENT PARTS

This section breaks down the components into their component parts. Only those component parts essential to understanding are listed. Others, such as mounting bolts, brackets, and chassis are not included.

.4 PRINCIPLES OF OPERATION

Up to this point, the system has been considered from a purely "static" point of view (What the System does). In this section, you will be called upon to evaluate the "dynamic" characteristics of the system. (How the components and component parts work together to perform the function of the system).

.5 MAJOR PARAMETERS

Obviously, all the numerical values in any given system need not be memorized, but a few are vital. This section asks for those numerical values (major parameters) that you must be able to immediately call to mind while operating and maintaining the equipment.

.6 SYSTEM INTERRELATIONS

Up to this point, your thinking has been directed to the system and its internal

operations. Now your thinking will be expanded to include how this system fits into the total picture: (How this system is affected by the operation of other systems, and how other systems are affected by the operation of this system).

.7 SAFETY PRECAUTIONS

Here you will be called upon to discuss any special safety precautions unique to this system. These unique safety precautions apply to personnel and/or equipment.

WATCHSTATIONS

The series on watchstations includes the procedures that must be known in order to properly operate and maintain the machinery. One should not let his thinking become limited to the concept that he stands watch only if his name is on a watch bill. In the qualification standards usage, a person is considered to be at his watchstation anytime he faces the machinery and uses his intelligence to cause it to perform correctly or try to analyze malfunctions. While all possible procedures may not be detailed in this section, the procedures that one can reasonably be expected to complete are covered by an OPERATOR and TECHNICIAN watchstation. These procedures are described in the following paragraphs.

Operator Watchstation

.1 OPERATING INSTRUCTIONS

As a result of your study of the 200 series of the qualification standard, you know what the systems do, how they do it, and many other aspects of their operation. You have spent a lot of time acquiring the necessary knowledge, all of which is of little value to you and the Navy unless you are able to use it to perform in an efficient manner. In this section, you will be directed to perform and discuss various aspects of procedures, demonstrating your ability to cope with the machinery at your watchstation.

.2 NORMAL OPERATIONS

Here you will be directed to describe those existing conditions that indicate the system is functioning properly.

.3 ABNORMAL CONDITIONS that could lead to EMERGENCIES and/or CASUALTIES

An abnormal condition is the first stage of a sequence of events that will lead to an emergency and/or casualty. You must be able to recognize the symptoms of these abnormal conditions and you must also know what immediate corrective action to take. In this section, you will discuss the more pertinent of the abnormal conditions.

.4 EMERGENCIES and/or CASUALTIES

In this section, you will discuss and/or perform, when practicable, the procedures for limiting the damage from the emergencies and casualties most pertinent to the watchstation.

.5 INFREQUENT and/or ABNORMAL OPERATIONS

This area is devoted to the discussion and/or performance, when practicable, of those procedures that are considered too dangerous, too time-consuming, or that occur too infrequently to be made mandatory performance items.

Technician Watchstation

.1 MAINTENANCE INSTRUCTIONS

In studying to be a technician, your operator knowledge will be expanded to include the maintenance of the equipments you have operated. In this section, you will be directed to discuss and perform the routine maintenance checks, tests, alignments, repairs, and replacements, that keep the equipment and machinery assigned to you in a "combat ready" condition.

.2 INFREQUENT and/or ABNORMAL MAINTENANCE OPERATIONS

As is true of the operator watchstation, there are infrequent and/or abnormal maintenance operations that are too time-consuming to make them mandatory performance items. In this section, you will be asked to discuss and perform those procedures when practicable.

QUALIFICATION CARDS

The recommended steps to be performed by a ship's service turbo-generator operator at a designated watchstation are shown in figure 10-2.

2402 WATCHSTATION - SHIPS SERVICE TURBO GENERATOR WATCH

Complete the following system qualifications:
2202, 2205, 2208, 2231, 2235, 2236, 2237, 2238 and 2239.

2402.1 Perform the following practical factors: (in accordance with the requirements set forth in 2302.1)

		SIGNATURE	DATE	POINTS
.11	Light-off, bring up to speed and secure a turbo generator			4
.12	Line-up, and secure Auxiliary Condensate System			2
.13	Line-up and secure Auxiliary Condenser Circulating Water System			2
.14	Line-up and secure the auxiliary air ejector			3
.15	Prepare the turbo generator for loading			2
.16	Observe and record temperature, pressure and levels on a turbo generator			2
.17	Shift, clean and inspect lube oil strainers			3

2402.2 Discuss with a qualified operator the conditions or evolutions listed below: (in accordance with the requirements set forth in 2302.2)

		SIGNATURE	DATE	POINTS
.21	Maintaining auxiliary condenser hot well level			
.22	Maintain proper lube oil			

2402.5 Discuss with or perform under the supervision of a qualified operator the following infrequent and/or abnormal operations: (in accordance with the requirements set forth in 2302.5)

		SIGNATURE	DATE	POINTS
.51	Operating with low or no vacuum			3
.52	Operating with auxiliary exhaust cut out of generator			2

2402.6 Stand a minimum of one satisfactory watch under qualified supervision.

SIGNATURE	REMARKS	DATE	POINTS
			8

Total Points This Page: 35
Total Points This Watchstation: 67

104.75.6
Figure 10-2.—Ship's service turbo-generator watch qualification card.

The qualification standards have been written so that upon completion of all sections, one will be able to both operate and maintain the machinery at his watchstation(s). In practice, however, where one starts in the standard will be determined by the need of the command. There, depending upon the immediate need for an individual's services, he will be given a qualification card that will tell him which section must be completed first.

The qualification cards reference the items you must complete in the 100, 200, and 300 series of the standard. The cards are your guide, reference, and record of achievement. The qualification cards are packaged separately from the standard and should be carried by you at all times to permit you to take advantage of every opportunity to complete the requirements.

ENGINEERING OPERATIONAL SEQUENCING SYSTEM (EOSS)

The main propulsion plants in ships of the modern Navy are becoming more technically complex as each class is built and joins the fleet. The increased complexity requires increased engineering skills for proper operation. Ships that lack the required trained personnel suffer material casualties which endanger their operational readiness. In addition, the rapid turnover of the engineering personnel who man and operate the ships further compounds the problem of training and maintaining a high level of operator and operating efficiency.

The Engineering Operational Sequencing System (EOSS) is designed to eliminate operational problems. EOSS involves the participation of all personnel from the department head to the fireman on watch. The EOSS consists of a set of plans and detailed written procedures utilizing charts, instructions, and diagrams developed specifically for the operational and casualty control task of a specific ship's engineering plant and configuration. EOSS improves the operational readiness of the ship's engineering plant by increasing its operational efficiency, providing better engineering plant control, reducing operational casualties, and extending machinery life.

The EOSS is comprised of three basic parts:

1. User's guide
2. Engineering operational procedures (EOP)
3. Engineering operational casualty control (EOCC)

USER'S GUIDE

The user's guide is a booklet explaining the EOSS package and how it is used to the ship's best advantage. It contains document samples and explains how they are used. Recommendations are included for introducing the EOSS system and methods of training the ship's personnel in utilizing these procedures aboard ship.

ENGINEERING OPERATIONAL PROCEDURES (EOP)

The operational portion of the EOSS contains all the information necessary for proper operation of the ship's engineering plant, as well as guides for scheduling, controlling, and directing plant evolutions. Although mechanical failure cannot be eliminated, proper operating procedures coupled with an efficient maintenance plan such as the Planned Maintenance Sub-System (PMS) are the keys to increased plant-up-time.

The EOP includes those systems and components that are directly related to the propulsion of the ship, generators, electrical distribution panels, and associated auxiliary supporting systems and components.

The propulsion system consists of the machinery that provides and delivers propulsive power to the ship. This system includes boilers, steam engines (reciprocating or turbine), internal combustion engines, and main motors for electric propulsion systems; fuel oil service, lube oil service, lube oil purification, combustion air supply, main steam, feed water, and condensate and main circulating water systems.

The electrical system consists of the machinery that produces and distributes ship service electric power. This system includes ship's service diesel, turbo and gas turbine generator sets with associated turbines, condensers, circulating and condensate system, and ship's service distribution switchboards.

The auxiliary system consists of, but is not limited to, the machinery to support the propulsion and electrical systems. This system includes auxiliary steam systems, auxiliary exhaust systems, distilling plants, fresh water drain collecting systems, low pressure drain collecting systems, compressed air systems, and steering gear machinery.

ENGINEERING OPERATIONAL CASUALTY CONTROL (EOCC)

The casualty control portion of the EOSS contains information relative to recognizing the

symptoms of a casualty and the causes and effects. In addition, it contains information on preventive action that may be taken to prevent casualties and procedures for controlling single and multiple casualties.

The EOCC manuals are in all machinery spaces so that they can be a means of self-teaching for newly assigned personnel.

WATCHSTANDING

Every watch in the engineering department is a vital part of an operation and maintenance program. How you, as a Machinist's Mate, stand your watch is very important to the reliability of the engineering plant. Certain types of machinery casualties may be caused by radical maneuvering of the ship or prolonged high speeds but there are times when such casualties reflect inadequate training, improper watchstanding, and too little preventive maintenance. Proper watchstanding and preventive maintenance always pay; you will spend less time tearing down machinery for overhaul. To properly stand an engineroom watch, you must be skilled in detecting unusual noises, vibrations, or odors which may indicate faulty machinery operation, as well as in taking appropriate and prompt corrective measures. You must be ready, in emergencies, to act quickly and independently; you must know the ship's piping systems and HOW, WHERE, and WHY they are controlled. You must know each piece of machinery: How it is constructed, how it operates, how it fits into the engineering plant, and where its related equipment is controlled. You must be skilled in reading and interpreting measuring instruments. You must understand how and why protective devices function (relief valves, speed limiting governors, overspeed trips, cut-in and cut out devices). You must remove fire hazards, stow gear that is adrift, and keep floor plates clean and dry. You must NEVER attempt to operate a piece of equipment that is defective. You must report all unsafe conditions.

Whatever your watch, you are responsible for knowing the status of every piece of machinery at your station, for promptly handling any necessary change in speed or setup, and for recording correctly all data concerning the operation and maintenance of the machinery. You must be sure that the log is up to date, that the status boards are correct, that you know what machinery is operating, and that you know what the night orders and standing orders are before you relieve the watch. Reporting the watch relieved means to the petty officer in charge that you know what the score is and have the situation under control. DON'T TRY TO RELIEVE THE WATCH FIRST AND FIND OUT THE SCORE LATER.

Your duties while on watch include not only the proper operation, care, and emergency repair of machinery in your charge, but also the recording of pertinent data on standard or ship forms provided for the purpose. It is essential, therefore, that you know what logs and records are kept, how to take the readings, when to take readings, and what should be immediately entered on the bell sheet or reported to the officer of the watch (OOW) for recording in his log.

The duties of the various watches vary in accordance with the size and type of ship, the layout of the ship, and the type of machinery installed. In general, Machinist's Mates stand watches at the main engine control station, at telephones, or miscellaneous engineroom machinery, on pumps and condensers, on compressors, on evaporators, on refrigeration machinery, in the steering engineroom, and in repair parties. Wherever you are on watch, you must know how to set various conditions of material readiness, and how to arrange split-plant and cross-connected operations at your station. Before standing any watch in the machinery spaces, familiarize yourself with the posted operating instructions and safety precautions for the particular pieces of machinery and equipment at your watch station.

As an MM3 or MM2, you must be able to stand the main engine control watch. This duty requires a thorough knowledge of control valve operating procedures and their use in conjunction with steam pressure and temperature, and ship's speed; a thorough knowledge of correct readings for control board gages, to detect instantly any abnormality; a knowledge of acceleration and deceleration tables; advanced knowledge of safety precautions pertaining to the main engines and associated auxiliaries, and the steps to be taken in cases of material casualty; and a general knowledge of fireroom operations insofar as they concern the engineroom operation.

Orders from the bridge relative to movement of the propellers must be complied with immediately. To make correct adjustments for

the required speed you must keep a close watch on the rpm indicator on the control board, and open and close the control valves as required to attain or maintain the necessary rpm. In addition to handling the controls, you may also have to operate various associated valves, accurately log all speed changes in the Engineer's Bell Book (fig. 10-3), visually check all gages (pressure, temperature, vacuum, etc.) installed on the control board, and keep the petty officer in charge informed of any abnormal gage readings.

The Engineer's Bell Book, NAVSHIPS 3120/1 shown in figure 10-3, is a record of all bells, signals, and other orders received by the throttleman regarding movement of the ship's propellers. Entries are made in the Bell Book by the throttleman (or an assistant) as soon as an order is received. Entries may be made by an assistant when the ship is entering or leaving port, or engaging in any maneuver which is likely to involve numerous or rapid speed changes. This procedure allows the throttleman to devote his undivided attention to answering the signals.

The Bell Book is maintained in the following manner:

1. A separate bell sheet is used for each shaft each day, except that where more than one shaft is controlled by the same control station, the same bell sheet is used to record the orders for all shafts controlled by the station. All sheets for the same date are filed together as a single record.

2. The time of receipt of the order is recorded in column number 1 (fig. 10-3).

3. The order received is recorded in column number 2. Minor speed changes (generally received via revolution telegraph) are recorded by entering the number of rpm ordered. Major speed changes (normally received via engine order telegraph) are recorded using the following symbols:

1/3—ahead 1/3 speed
2/3—ahead 2/3 speed
I—ahead standard speed
II—ahead full speed
III—ahead flank speed
Z—stop
B1/3—back 1/3 speed
B2/3—back 2/3 speed
BF—back full speed
BEM—back emergency speed

4. The number of revolutions corresponding to the major speed change ordered is entered in column 3. When the order received is recorded as rpm in column 2 (minor speed changes), no entry is made in column 3.

5. The shaft revolution counter reading at the time of the speed change is recorded in column 4. The shaft revolution counter reading—as taken hourly on the hour, while underway—also is entered in column 4.

Ships and craft equipped with controllable reversible pitch propellers record in column 4 the propeller pitch in feet and fractions of feet set in response to a signaled speed change, rather than the shaft revolution counter readings. The entries for astern pitch are preceded by the letter B.

Before going off watch, the engineering officer of the watch signs the Bell Book in the line following the last entry for his watch and the next officer of the watch continues the record immediately thereafter. In machinery spaces where an engineering officer of the watch is not stationed, the bell sheet is signed by the watch supervisor. The Bell Book is a legal record and alterations or erasures are not permitted. An incorrect entry is corrected by drawing a single line through the entry and recording the correct entry on the following line. Deleted entries are initialed by the engineering officer of the watch or watch supervisor, as appropriate.

PROCEDURE FOR PLACING PLANT IN READINESS FOR GETTING UNDERWAY

The engineroom operating procedures which follow include the steps usually taken in operating geared turbine installations on ships with two enginerooms.

A general checkoff sheet or table of instructions to be followed in getting a turbine installation ready for getting underway is usually provided on each ship. These instructions and the specified times of accomplishment of various items will differ from ship to ship in accordance with the type of installation, the particulars of machinery design, the particulars of machinery arrangement, and with the instructions issued by the engineer officer. The steps included in the following list are representative of those to be taken in placing a particular steam-driven

ENGINEER'S BELL BOOK - ALL VESSELS
NAVSHIPS 3120/1 (Rev. 10-69) (Formerly NAVSHIPS 116)
S/N 0105-601-9462

ENGINEER'S BELL BOOK

		SHIP TYPE		HULL NUMBER	SHEET SERIAL	YEAR	MONTH	ZONE	DAY		SHAFT NUMBER(S)	CLASS	HANDL
D	A	CA	—	132	Ø1	2	Ø7	Z	14	J	1 2 3 4	U	
1	2	3 - 4		5 - 7	10 - 11	12	13 - 14	15	16 - 17	22	74 - 77	78	79

Sample (CAG-132)
Ship Name

Record of all "BELLS," SIGNALS, and ORDERS received regarding movement of propellers this date.

En route from Norfolk, Va. to Cadiz, Spain Clocks set back or ahead 1 hrs. 0 min., at 1800

(1) TIME	(2) SIGNAL	(3) R.P.M.	(4) COUNTER OR PITCH SET	(1) TIME	(2) SIGNAL	(3) R.P.M.	(4) COUNTER OR PITCH SET	(1) TIME	(2) SIGNAL	(3) R.P.M.	(4) COUNTER OR PITCH SET
18 - 21	24 - 28	29 - 32	33 - 38	18 - 21	24 - 28	29 - 32	33 - 38	18 - 21	24 - 28	29 - 32	33 - 38
01	Counter		214625	R.E. Digger, M.M.3 U.S.N.							
02	Counter		223085	E.L. Swann, Lt. U.S.N.							
03	Counter		231545	20	Counter		365249				
J. Wise M.M.F.N., U.S.N.				21	Counter		373709				
E.L. Swann Lt. U.S.N.				22	Counter		382164				
04	Counter		240005	23	Counter		390629				
~~05~~	~~Counter~~		~~24846~~	W.T. Doe, F.N.							
05	Counter		248465	J.B. James, E.N., U.S.N.							
06	Counter		256925	24	Counter		400089				
07	Counter		265385	J. Wise M.M.F.N. U.S.N.							
R.E. Digger M.M.3 U.S.N.				G.A. Bartlett, C.W.O. U.S.N.							
J.B. James, E.N. U.S.N.											
08	Counter		273845								
09	Counter		282305								
10	Counter		290765								
1002	2/3	45.0	291047								
1040	1	141.0	294777								
11	Counter		297569								
W.T. Doe, F.N.											
G.A. Bartlett, C.W.O., U.S.N.											
12	Counter		306029								
13	Counter		314489								
14	Counter		322949								
15	Counter		331409								
J. Wise, M.M.F.N. U.S.N.											
A. Walton, C.W.O.3, U.S.N.											
16	Counter		339869								
17	Counter		348329								
19	Counter		390629								

77.230
Figure 10-3.—Engineer's Bell Book.

propulsion plant in readiness for getting underway.

1. Take and record turbine rotor positions, enter in log specifying cold readings.

2. Back off throttle valves and reseat lightly.

3. Operate hand nozzle control valves.

4. Open all funnel drains on main steam line and turbine valve chest. (When steam blows through, close funnel drains and cut in high pressure drain traps.)

5. Have Electrician's Mates energize and test all power and I.C. circuits.

6. Check oil levels in sump, pumps, and main shaft bearings.

7. Check cooling main, ensure adequate cooling water to all auxiliary machinery.

8. Assure proper temperature of oil and start a lube oil service pump. Check oil delivery to all bearings and check lube oil system for leaks.

9. Energize and test low pressure lube oil alarm. Warm up standby lube oil service pump and test automatic cut-in devices.

10. Cut in cooling water to stern tubes, allow a small amount of water to leak through gland.

11. With permission from the officer of the deck (OOD), engage turning gear (jacking gear) and start turning main engines.

12. Open main injection and overboard discharge valves, vent main condenser.

13. Start main circulating pump. Do not operate with less than 125 to 150 psi steam chest pressure.

14. Start a main condensate pump, recirculate condensate through the air ejector condenser back to the main condenser.

15. Cut in steam to main turbine gland seal and start gland exhaust fan.

16. Cut in steam slowly to second stage of main air ejectors.

17. Warm up one main feed booster pump and one main feed pump.

18. Shift from emergency feed pump to main feed pump. (Secure emergency feed pump in standby condition.)

19. Open wide the bypasses on the main steam bulkhead stop and main engine guarding valve.

20. Start warming up the main steam line by cracking open the main steam boiler stop valve bypass.

21. Open the drains from the whistle and cut in steam to the whistle slowly.

22. When main condenser vacuum reaches 20 inches, shift auxiliary exhaust and low pressure drains to main condenser.

23. Have Electrician's Mates test steering engines and anchor windlass. Report results of tests to main control.

24. Warm up and test standby auxiliary machinery: condensate pump, main feed booster pump, and main feed pump.

25. Warm up an additional ship's service turbogenerator.

26. When the required number of boilers are on the line, split the following systems: main steam (if applicable), auxiliary steam, 150 psi steam, auxiliary exhaust, high pressure drains, low pressure drains, main condensate, makeup feed, fireman, inspection tank (fuel oil heater) drains, and (if applicable) turbo-generator steam. Parallel and then split the electrical load.

27. Man the 1JV and 2JV phones in all main propulsion spaces.

28. Request permission from the OOD to test main engines.

29. Stop and disengage the turning gear, open wide the main steam bulkhead stop and the main engine guarding valve 3 turns.

30. Test the main engines by spinning astern and then ahead.

31. When main engines have been tested satisfactorily, open wide the main engine guarding valve and bulkhead stops. Report engineering department readiness for getting underway to the OOD and to the engineer officer. Then cut steam into the first stage of the main air ejectors.

32. Request permission from the OOD to spin main engines every 3 to 5 minutes, and record for entry in the smooth log.

33. Take and log main engine "hot rotor position" readings.

34. Get underway when ordered.

35. Close main turbine drains.

NOTE: Information related to some of the preceding steps in the procedures for warming up the main plant is identified as step 1, step 2, etc., and is given for cross-reference.

For details on taking turbine rotor position readings (step 1), refer to chapter 3 of this training manual.

Steps 6, 8, and 9 deal with lubrication and the main plant lubrication system. A review of chapter 9 of this training manual before studying the information in the following paragraphs will be helpful at this point.

When preparing to get underway, the first step in connection with lubrication is to check the amount of oil available. A float gage indicates the oil level (in gallons) in the main engine sump. Dip sticks are used to check the oil level in auxiliary machinery sumps and main shaft bearings. The need for cleanliness, at all times, in the operation of lubricating systems must be constantly kept in mind. Lubricating oil will lose its lubricating qualities if it is contaminated; if the impurities (water or other foreign matter) are removed, the oil can be used over and over. The entire lubrication system must be given constant careful attention to ensure that the oil is kept free of foreign matter.

Each time a lubrication system is put into operation, all parts of the system must be in satisfactory operating condition; to ensure that it is, proceed as follows:

a. Take and record the oil level.

b. Inspect and clean strainers.

c. Start a lube oil service pump and maintain the designed pressure throughout the system. Automatic cut-in devices for all lube oil service pumps should be tested. Motor-driven pumps should be tested on alternate sources of power. Turbine-driven pumps should be operated satisfactorily on their constant pressure governors.

d. The temperature of the oil supplied to the main engines and reduction gears must be at least 90° F before the unit is turned over. If the oil is below this temperature, it can be heated by use of the purifier heater, by use of sump heaters, or by use of the auxiliary exhaust connection to the lube oil cooler, depending upon the arrangement.

e. An adequate supply of cooling water must, at all times, be available to the lube oil cooler. When the cooler is put into use, open wide the cooling water inlet valve, open the cooling water vent valves until all air is expelled, then close the vent valves. After the oil leaving the cooler reaches 120° F, regulate the temperature of the oil by opening or closing down on the overboard valve.

f. Observe pressure gages to determine that oil pressure is correct, and pour into sight flow fittings to ascertain that oil is flowing through the bearings. Inspect the lubricating system for leaks. Any trouble found must be corrected.

g. Test the emergency cooling connections, if fitted.

h. Test the low lube oil pressure alarm by decreasing the oil pressure until the alarm sounds. If the alarm does not sound at the proper pressure, remedy the defect at once.

i. While underway, draw a sample of oil at least once each watch, from the sump or from the strainer in use. Compare the sample with previous samples to determine whether any water has collected in the system. To test the operation of the purifier, draw a sample of oil from the purifier test cock. Check for water or other impurities by comparing sample with previous samples.

Step 11. Never turn the main engines over without permission of the officer of the deck. A screw may hit a boat, barge or some other floating object or a mooring line or wire may be in a position to foul the screw. The officer of the deck will ensure that the area near the screws is clear before granting permission to turn the main engines.

Step 13. When operating in cold water, standing by, or steaming at slow speeds, the cooling water requirements for the main condenser are greatly reduced. However, the main circulating pump MUST NOT be operated with less than 125 to 150 psi steam chest pressure. At a steam pressure less than 125 to 150 psi the speed of the pinion-driven oil pump will not be high enough for the pump to deliver an adequate supply of oil to the lubrication system of the driving unit.

Steps 15 and 16. Never cut in gland sealing steam until the turning gear is engaged and started. The gland exhauster and the second stage of the main air ejector should be placed in operation just prior to, or simultaneously with, the admission of gland sealing steam. The first stage of the main air ejectors should not be placed in operation until after the turning gear has been disengaged.

Steps 18-20. When the steaming boiler is receiving feed water from the main feed pump, the auxiliary or emergency feed pump may be secured in a standby condition. In the event of a main feed casualty, the emergency feed pump is ready for immediate use and can prevent a loss of ship's electrical power or a boiler casualty.

Under normal warming-up conditions, the main steam stop bypass valve should not be opened until the main feed pump is feeding the

boiler. This reduces the load that would otherwise be put on the emergency feed pump.

The procedure for warming the main steam line will vary from ship to ship. On most combatant ships the procedure is as follows:

a. Open (1 to 1 1/2 turns) the low pressure (funnel) drain valves.

b. Open the bypass valves on the main engine guarding valve, the bulkhead or line stop valve(s), and the main steam split-plant valve.

c. Crack open the bypass valve on the main steam boiler stop valve.

d. When the pressure in the main steam line reaches 50 psi, cut in the high pressure drain traps and secure the low pressure (funnel) drains.

e. When the plant is split, secure the bypass on the main steam split-plant valve.

f. When permission has been granted to test main engines, open the main steam boiler stop valve and the line or bulkhead stop or stops. The turning gear must be stopped and disengaged before the main engine guarding valve is opened. Open the guarding valve and bulkhead stop ONLY 3 TURNS; this serves as a safety measure in the event that a casualty occurs. For example, if a nozzle control valve or astern throttle sticks open while the main engines are being tested, the main engine guarding valve or bulkhead stop can be closed very quickly, from the 3-turn position. When engines have been tested satisfactorily, open bulkhead stop and guarding valve wide.

WARMING UP THE MAIN TURBINES

In warming up a turbine it is well to remember that the rotor and the casing must be evenly heated; otherwise, unequal expansion will take place and will produce distortion of the rotor or the casing or both. The results of such distortion are not as noticeable in small turbine installations as in large installations; however, the cumulative effect of distortions due to temperature change and unequal expansion is very noticeable, and unless extreme care is taken, serious damage, such as rubbing of blades or packing, will result.

When you are standing watch in the engineroom you should be able to detect any unusual rubbing or grinding sounds and be able to locate the trouble quickly. At any time that an unusual noise is detected, the turbine should be stopped immediately in order to prevent damage to the installation. No unusual sound is so trivial that it can be neglected. A listening rod will be helpful in detecting faint or indistinct sounds.

Two procedures are used in the warming up of a turbine: turning the turbine; and spinning the turbine. The turning procedure is used during a normal warming up; the spinning procedure is used when the ship is standing by to get underway and the turning gear has been disengaged.

Turning the Main Engines

During warming up or cooling-off of the turbine, the rotor must not be permitted to remain at rest for any appreciable time while steam (including gland steam) is being admitted to the turbine. The turning gear should be put into operation to turn the turbine rotor before steam is admitted to the turbine glands.

Spinning the Main Engines

After the main engines have been tested satisfactorily and while you are waiting to answer bells, the main engines must be turned by steam. The engines are spun astern and then ahead, to prevent putting way on the ship. Spinning the engines by steam not only heats the turbines and their casings, but also prevents the rotors from becoming bowed. When the turbine is ready to be rolled, open the throttle wide enough to admit sufficient steam to start the rotors turning. If the rotor does not turn, steam will hit only a small portion of the blading and cause uneven heating.

PROCEDURES FOR STANDING BY

When orders are received to stand by, the procedure to be followed will depend on the length of time that the ship is to remain in "stand by" condition.

Standing By Indefinitely

When a ship is standing by for an indefinite period of time, the condition of the main propulsion plant will depend upon how much time has been allowed to change from "stand by" condition to "ready to answer bells" condition. The principal variations will be in the number of boilers left on the line, the number of auxiliaries in use, and whether or not the plant will be cross-connected. If the ship is standing

by for an hour or more the following steps may be taken:

1. Close the main engine guarding valve.
2. Secure the first stage of the main air ejectors.
3. Engage and start the turning gear.
4. Cross-connect the main plant and secure all boilers that are not necessary. (On a large ship having four screws, a two-plant setup may be used, the two forward plants cross-connected with one boiler steaming and the two after plants cross-connected with one boiler steaming. In this setup, the systems will remain split between the two forward plants and the two after plants. On a destroyer, or other small ship, only one boiler is necessary.)
5. Use one lube oil service pump in each engineroom, maintain the required lube oil pressure to the bearings and reduction gears.
6. Maintain the required lube oil temperature.
7. Maintain the gland sealing steam at 1/2 to 2 psi.
8. Run the main circulating pump, using 125 to 150 psi steam chest pressure.
9. Use one main feed booster pump and one main feed pump to feed the steaming boiler.
10. Close the main steam boiler stop valve on the steaming boiler; open the main steam bypass valve. (If the turbo-generators receive steam from the main steam line, the main steam boiler stop valve will remain open.) Every effort should be made to operate the plant economically, the main feed pump discharge pressure can be lowered to about 75 psi higher than boiler operating pressure. Drain valves from the main steam line and main engines should be cracked open; however do not open low pressure funnel drains an excessive amount, because this wastes feed water, causes high fuel oil consumption, and raises the temperature of the engineroom.

Standing By On Thirty-Minute Notice

When a ship is standing by with orders to get underway in thirty minutes, the following steps may be taken:

1. Close the main engine guarding valve.
2. Engage and start the turning gear.
3. Secure the first stage of the main air ejectors.

NOTES ON TURBINE OPERATION

Underway procedures must be carried out in a manner that enables the ship to accomplish its mission with the greatest operating economy possible. Economical and efficient operation of a propulsion plant, under varying conditions and speeds, necessitates the maintenance of a high vacuum and the proper use of the cruising and maneuvering combinations.

IMPORTANCE OF HIGH VACUUM

In order to attain the greatest operating economy, the vacuum for which the turbine was designed must be maintained. Therefore, you should realize the necessity for the prevention and detection of air leaks in the vacuum system.

When the steam pressure within the turbine is greater than atmospheric pressure, steam tends to leak out of the turbine to the surrounding atmosphere. On the other hand, when the pressure in the turbine is less than that of the atmosphere, air tends to leak into the turbine and impair the vacuum. To prevent air leakage into the turbine and steam leakage from the turbine, steam is led to the glands and the pressure on the glands is maintained slightly greater than that of the atmosphere, generally 1/2 to 2 psi.

To ensure that the optimum vacuum will be maintained, care must be taken that the astern throttles do not leak; any leakage of steam past a closed throttle tends to raise the temperature and to increase the pressure within the turbine.

If the following precautions are observed, there will be little difficulty in maintaining the prescribed vacuum:

1. Gland packing must be kept in good condition.

2. A steam pressure between 1/2 and 2 psi must be maintained on the glands when the turbines are in operation.

3. There must be no air leaks in the condenser, exhaust trunks, throttles, lines to air ejectors, gage lines, idle condensate pump packing and valves, makeup feed lines, etc.

4. Adequate water must be maintained in the feed tank on which the vacuum drag is being taken.

CRUISING COMBINATIONS

A combatant ship operates most of the time at speeds far below the maximum; at cruising speeds, therefore, there is required only a fraction of the power for which the main turbines are designed. Operating economy at these lower speeds is attained (1) by the use of cruising turbines, which are specially designed to operate at reduced speeds, or (2) by the use of cruising stages in the high pressure turbines, and (3) by arranging the turbines so that they can be run in series. The cruising combinations should be used whenever the standard speed is such that the combination can furnish the required number of revolutions.

PROTECTION OF CRUISING TURBINES

Protective devices and indicating instruments are required to prevent casualties to cruising turbines. Devices and instruments installed on cruising turbines for this purpose include sentinel valves, relief valves, retard-compound gages, direct reading thermometers, and thermal alarms.

When a ship is operating on cruising turbine combination, the following precautionary measures should be taken at frequent intervals to prevent casualties to the cruising turbine.

1. Be sure that the crossover valve is fully shifted to the proper combination.
2. Check the retard-compound gage to be sure that the safe operating pressure is not exceeded.
3. Check the sentinel valve frequently. If there is steam blowing from the sentinel valve, the safe operating pressure is being exceeded.

TURBINE VIBRATION

If a turbine begins to vibrate as its speed is increased, the turbine should be slowed down immediately. If the vibration ceases at a lower speed, maintain that speed for several minutes; then attempt to build up the speed again. If no further vibration is noted, it may be assumed that the trouble was probably due to unequal heating of the rotor or to an accumulation of water in the turbine. If the vibration does not cease at a lower speed the turbine must not be used, except in an emergency; and steps must be taken immediately to locate and remedy the trouble. If, after the turbine has been running at a reduced speed for some time, the vibration again occurs at the higher speed, a speed limit lower than that at which vibration occurs must be set; and this reduced speed must not be exceeded until the trouble has been eliminated.

USE OF NOZZLES

In all modern installations, the flow of steam to the cruising and high pressure turbines is controlled by the nozzle control valve arrangement. These valves are a lifting beam mechanism. The lifting beam mechanism consists of a steel beam drilled with holes which fit over the nozzle valve stems. The valve stems are of varying lengths and are fitted with shoulders at the upper ends. When the beam is lowered, all valves rest upon their seat. When the beam is raised, the valves open in succession, depending upon their stem length—the shorter ones open first, then the longer ones.

It is essential that the pressure in the steam chest be kept as high as practicable. High pressure here allows for greater steam expansion and a resulting increase in the useful work obtained from the steam. The fewer the nozzles in use, the higher will be the chest pressure.

TURBINE BLADE CLEARANCE

In an impulse turbine, the axial distance of the moving blades from the casing or the stationary blades is known as the axial (fore-and-aft) blade clearance. This clearance may be determined by means of a finger piece, a rotor-position indicator, or a clearance indicator.

A ready visual check on the fore-and-aft position of the turbine rotor may be obtained from the FINGER PIECE. Most finger pieces consist of an indicator which extends almost to the shaft, fastened to a plate which is secured to the turbine case. Usually three lines are scribed on the shaft to show the normal position and the maximum positions. In some finger pieces, the indicator extends into a groove in the shaft and the distance from the indicator to the shaft shoulder may be measured with feelers to determine fore-and-aft clearance.

The axial position of a turbine rotor may be determined with a ROTOR-POSITION INDICATOR. This instrument can be used when the rotor is either revolving or at rest. The indicator is mounted at the forward end of the turbine shaft, with the spindle in line with the

centerline of the shaft. When the indicator is being used, the spindle contacts the end of the shaft at the center. The reading obtained is compared with established limits to determine if the position of the shaft is satisfactory. Care must be exercised to prevent the end of the indicator spindle from becoming worn by long or hard contact with the rotating shaft.

In some installations, the axial blade position of a turbine rotor is determined with a ROTOR-POSITION INDICATOR. The indicator may be used when the turbine is in operation. The instrument consists of a scale plate and an indicator, mounted within a bracket which is bolted to the turbine casing. The scale plate has scribed lines showing the normal position (midposition) and the maximum and minimum (forward and aft) positions. One end of the indicator is made in the shape of a pointer, and a roller or contact surface is mounted on the other end. The indicator operates on a pivot. To take a reading, it is only necessary to press the arm of the indicator so that contact is made between the shaft and the roller, and then note the position of the pointer on the scale.

ROUTINE UNDERWAY INSPECTIONS

Periodic inspections of the propulsion plant must be made if the plant is to be kept operating efficiently. When a ship is underway, the following items should be checked or inspected at very short intervals during each watch:

1. Check all main engine and reduction gear bearing thermometers to detect signs of overheating.
2. Check oil sight-flow indicators for proper oil flow.
3. Check clearance indicators for proper rotor position.
4. Check all thermometers, pressure gages, and vacuum gages.
5. Check the oil level in the main sump.
6. Maintain the proper water level in the deaerating feed tank.
7. Keep a constant check on salinity indicators.
8. Check the lube oil temperature from the lube oil cooler, maintain oil temperature at 120° to 130° F.
9. Check the cooling water main for proper pressure.
10. Constantly be on the alert for unusual sounds and vibrations.
11. Each watch, clean lube oil and bilge strainers.

Usually, the first indication of bearing trouble will be a rise in temperature. There is no objection to a bearing running warm, provided the temperature reached is not sufficient to harm the bearing. What must be guarded against is a rapid rise in temperature and an increase over the normal operating temperature. If the bearing temperature increases above normal, the quality and quantity of lubricating oil must be checked. If possible, increase the supply of oil to the bearing and increase the flow of cooling water through the oil cooler. If these measures do not reduce the bearing temperature, the unit must be slowed or stopped.

A sight-flow indicator is fitted in the lube oil line of each main engine bearing and each reduction gear bearing on most units. When a lube oil service pump is in operation, each indicator should show a steady flow of lube oil. Frequent inspections of the sight-flow indicators should be made in order to detect any interruption to the flow of lube oil.

Each hour, the rotor-position indicator for each turbine is checked and the rotor position logged to help determine the position of the rotor in respect to the casing. Any abnormal reading must be thoroughly investigated. Should the rotor move sufficiently for the moving blades to strike the stationary blades or nozzles, great damage would result.

One of the first indications of engineroom trouble is an abnormal reading on a thermometer or gage. All thermometers and gages must be checked frequently to detect and prevent casualties. It should never be taken for granted that an abnormal reading is due to the fault of the gage or thermometer. The accuracy of a gage or thermometer may be easily checked by replacing it with one that has been calibrated.

Each hour, the oil level in the main engine sump is to be checked and logged in the main engine operating record. However, more frequent checks should be made. An increase in the oil level generally means that water is entering the lube oil system or that the system is gaining oil in some improper manner. The lube oil purifier may be lined up wrong. A decrease in the oil level of the main engine sump usually indicates a leak in the lube oil system or that the lube oil purifier is discharging oil through the impurity discharge.

An increase or a decrease in the main sump oil level should NEVER be neglected. It could result in a temporary loss of a main engine, or even costly repairs to main engine bearings and reduction gears.

For safe efficient operation, the water level in a steaming deaerating feed tank should be kept within the normal operating range. If the water level is allowed to go above the maximum level, the deaerating effect is lost. Admitting large quantities of comparatively cold water to the deaerating feed tank will reduce the pressure in the tank. This reduces the main feed booster pressure, which may result in casualties to the main feed pump and boiler.

If the water level is below minimum, a sudden demand for feed water for the boilers may empty the deaerating feed tank. This may well result in casualties to the boiler, the main feed booster pump, and the main feed pump.

A salinity indicator meter is located on or near the throttle board in each engineroom, to detect the entrance of salt water into the condensate system. The meter must be constantly checked as a small amount of salt in the condensate system will contaminate a steaming boiler beyond allowable limits. An abnormal reading (0.1 epm or above) must be checked and the source of contamination eliminated. More information on salinity indicators may be found in chapter 14 of this training manual, and the appropriate manufacturer's technical manuals.

A properly operating main engine and reduction gear installation has a definite sound which trained personnel can recognize. Any abnormal sound should be investigated and the unit operated with caution until the cause is found and remedied.

PREPARATIONS FOR ANCHORING AND SECURING

After the control engineroom has been notified as to the time the ship will enter port, the necessary preparations must be made to secure the main engines. Personnel should be notified and given specific instructions for setting up the in-port auxiliary watch. The auxiliary machinery to be used in port must be placed in operation, the deck machinery used in anchoring must be tested and numerous other tasks must be accomplished.

SETTING SEA DETAIL

On installations where the turbogenerators exhaust to either the auxiliary or the main condenser, the following procedure should be followed in setting sea detail:

1. Man the 1JV and 2JV sound-powered telephone.
2. Put the auxiliary condenser in operation, shift the turbogenerator exhaust from the main condenser to the auxiliary condenser.
3. Start the standby turbogenerator, parallel with generators in use, and then split the electrical load.
4. Warm up the main circulator. (Open the turbine exhaust valve, close the turbine casing drain when steam blows through, and drain the steam supply line.)
5. If not already done, split the plant as ordered by the engineer officer. Start the main circulating pump (when necessary).
6. Open turbine drains on the first stop bell.
7. Cooling water to lube oil cooler should be adjusted to maintain the lube oil from the cooler at 120°.

SECURING MAIN ENGINES

Each ship has its own detailed form for securing main engines. The following procedure (engineroom only) is given as an example.

1. Secure and lock closed the throttle valves and close the main engine guarding valve. Close the main steam boiler stop valve and drain the main steam line and turbines.
2. Secure the first stage of the main air ejector.
3. Engage and start the turning gear.
4. Cross-connect the plant.
5. Shift the electrical load to the generator designated for in-port use and secure the standby generator.
6. Shift the high pressure drains, low pressure drains, and the auxiliary exhaust to the steaming engineroom.
7. Secure the following standby pumps:

   a. Lube oil service pump.
   b. Main feed pump.
   c. Main feed booster pumps.

8. Start the auxiliary feed booster pump (if installed) and the emergency feed pump.

9. Secure the main feed pump and then the main feed booster pump.

10. Shift the auxiliary exhaust and low pressure drains to the auxiliary condenser.

11. Secure the second stage of the main air ejectors.

12. Secure gland sealing steam (when main condenser vacuum drops to 10 inches of mercury).

13. Secure main circulating pump when the exhaust trunk temperature drops to near room temperature. Close the main injection and overboard valves.

14. Close all throttle, root, exhaust, and drain valves not in use. Secure all unnecessary vents.

15. Stop and disengage turning gear. (Time will depend on type of ship.)

16. When oil has cooled to room temperature, secure lube oil service pump and drain waterside of oil cooler.

17. Report main engines secured to duty officer and OOD.

18. Twenty-four hours after securing, close turbine and steam line drains.

As previously stated, operating procedures vary from ship to ship. The information given in this chapter is general. For example, in step 14 of the securing schedule, no specific time can be given for securing the main circulating pump. On a World War II destroyer, the time may be one hour; while on a Forrestal class carrier, the main circulating pump may be run 18 to 24 hours after the main engines are secured. For any particular ship the best sources of information are the ship's warming-up schedule, operating instructions, securing schedule, and specifid instructions issued by the engineer officer.

CHAPTER 11

REFRIGERATION

As a Machinist's Mate, you should have a knowledge of refrigeration and air conditioning systems. From practical experience, you will probably learn how to start, operate, stand watch on, and secure these systems. To do your job properly, you must have a thorough understanding of the operating principles of refrigeration systems. This understanding can be attained through study.

The refrigeration systems most commonly used in the Navy, utilize R-12 as a refrigerant. Chemically, R-12 is dichlorodifluoromethane (CCl_2F_2). The boiling point of R-12 is so low that the substance cannot exist as a liquid unless it is confined and put under pressure. It also has the advantage of being practically nontoxic, nonflammable, nonexplosive, and noncorrosive; and it does not poison or contaminate foods. The information given in this chapter is, therefore, primarily concerned with R-12 systems. It should be noted that the cycle of operation and the main components of R-12 systems are basically the same for refrigeration and air conditioning plants.

FUNDAMENTALS OF REFRIGERATION

Refrigeration is a general term used to describe the process of removing heat from spaces, objects, or materials and to maintain them at temperatures below the temperature of the surrounding atmosphere. In order to produce a refrigeration effect, it is merely necessary to expose the material to be cooled to a colder object or environment and allow heat to flow in its NATURAL direction—that is, from the warmer material to the colder material. The term is usually applied to an artificial means of lowering the temperature. Mechanical refrigeration may be defined as a mechanical system or apparatus so designed and constructed that, through its function, heat is transferred from one substance to another.

Refrigeration is more readily understood if you know the relationships among temperature, pressure, and volume, and how pressure affects liquids and gases.

HEAT

The purpose of refrigeration is to maintain spaces at low temperatures. Remember, however, that you can't cool anything by adding coolness to it; you have to REMOVE HEAT from it. Refrigeration, therefore, is a process of cooling by removing heat.

Heat and Temperature

It is important to distinguish between heat and temperature. HEAT is a form of energy. TEMPERATURE is the intensity of heat. The quantity or amount of heat is measured in terms of a standard unit called a BRITISH THERMAL UNIT (Btu). Temperature, as you know, is measured in degrees, which indicate the intensity of the heat in a given substance; it does not indicate the number of Btus in the substance. For example, let's consider a spoonful of very hot water and a bucketful of warm water. Which has the higher temperature? Which has more heat? The heat in the spoonful of hot water is more intense; therefore, its temperature is higher. The bucketful of warm water has more Btu (more heat energy), but its heat is less intense.

Sensible Heat and Latent Heat

In the study of refrigeration, it is necessary to distinguish between sensible heat and latent heat. SENSIBLE HEAT is the term applied to the heat that is absorbed or given off by a

substance that is NOT in the process of changing its physical state. When a substance is not in the process of changing its state, the addition or removal of heat always causes a change in the temperature of the substance. Sensible heat can be sensed, or measured with a thermometer.

LATENT HEAT is the term used to describe the heat that is absorbed or given off by a substance while it is changing its physical state. When a substance is in process of changing its physical state, the heat absorbed or given off does NOT cause a temperature change in the substance—the heat is latent or hidden. In other words, sensible heat is the term used to describe heat that affects the temperature of things; latent heat is the term used to describe heat that affects the physical state of things. Additional information on sensible heat and latent heat is given in chapter 3 of Fireman, NAVPERS 10520-D.

Specific Heat

Substances vary with respect to their ability to absorb heat or to lose heat. The ability of a substance to absorb heat or to lose it is known as the SPECIFIC HEAT of the substance. The specific heat of water is taken to be 1.0, and the specific heat of each other substance is measured by comparison with this standard. Thus, if it takes only 1/2 Btu to raise the temperature of 1 pound of a substance 1° F, the specific heat of that substance is 0.5, or one-half the specific heat of water. If you look up the specific heat of ice in a table, you will find it to be about 0.5.

Heat Flow

Heat flows only from objects of higher temperature to objects of lower temperature. When two objects at different temperatures are placed near each other, heat will flow from the warmer object to the cooler one until both objects are at the same temperature. Heat flow takes place at a greater rate when there is a large temperature difference than when there is only a slight temperature difference. As the temperature difference approaches zero, the rate of heat flow also approaches zero. Heat flow may take place by radiation, by conduction, by convection, or by some combination of these methods.

Refrigeration Ton

The unit which measures the amount of heat removal and thereby indicates the capacity of a refrigeration system is known as the REFRIGERATION TON. The refrigeration ton is based on the cooling effect of 1 ton (2000 pounds) of ice at 32° F melting in 24 hours. The latent heat of fusion of ice (or water) is 144 Btu. Therefore, the number of Btu required to melt 1 ton of ice is 144 x 2000, or 288,000. The standard refrigeration ton is defined as the transfer of 288,000 Btu in 24 hours. On an hourly basis, the refrigeration ton is 12,000 Btu per hour (288,000 divided by 24).

It should be emphasized that the refrigeration ton is the standard unit of measure used to designate the heat-removal capacity of a refrigeration unit. It is not necessarily a measure of the ice-making capacity of a machine, since the amount of ice that can be made depends upon the initial temperature of the water and other factors.

PRESSURE, TEMPERATURE, AND VOLUME

In studying refrigeration, it is important to understand some of the ways in which pressure affects liquids and gases, and some of the relationships between pressure, temperature, and volume in gases.

The boiling point of any liquid varies according to the pressure on the liquid—the higher the pressure, the higher the boiling point. It is well to remember that condensing a gas to a liquid is just the reverse process of boiling a liquid until it vaporizes, and that the same pressure and temperature relationship is required to produce either change of state.

Water boils at 80° F under a vacuum of 29 inches of mercury; at 212° F at atmospheric pressure; and at 489° F at a pressure of 600 psig. Refrigerants used in vapor compressor cycle equipment usually have much lower boiling points than water, under any given pressure, but these boiling points also vary according to pressure. R-12, for example, boils at -21° F at atmospheric pressure; at 0° F at 9.17 psig; at 50° F at 46.69 psig; and at 100° F at 116.9 psig. From these figures, you can see that R-12 cannot exist as a liquid at ordinary temperatures unless it is confined and put under pressure.

If the temperature of a liquid is raised to the boiling point corresponding to its pressure,

and if the application of heat is continued, the liquid begins to boil and vaporize. The vapor which is formed remains at the same temperature as the boiling liquid, as long as it is in contact with the liquid. A vapor CANNOT be superheated as long as it is in contact with the liquid from which it is being generated.

The pressure-temperature-volume relationships of gases are expressed by Boyle's law, Charles' law, and the general gas law or equation.

BOYLE'S LAW states that the volume of any dry gas varies inversely with its absolute pressure, provided the temperature remains constant. This law may also be expressed as an equation:

$$V_1 P_1 = V_2 P_2$$

where V_1 is the original volume of the gas, P_1 its original absolute pressure, V_2 its new volume, and P_2 its new absolute pressure.

CHARLES' LAW states that the volume of a gas is directly proportional to its absolute temperature, provided the pressure is kept constant. The equation for this law is:

$$V_1 T_2 = V_2 T_1$$

THE GENERAL GAS EQUATION combines Boyle's law and Charles' law, and expresses the relationship between the volume, the absolute pressure, and the absolute temperature of gases. The general gas law is expressed by the equation:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

These equations indicate the nature of the relationship between the pressure, the volume, and the temperature of any gas. You will probably not find it necessary to use the equations themselves, but you should have a thorough understanding of the principles which they express. Let's summarize them:

1. When temperature is held constant, increasing the pressure on a gas causes a proportional decrease in volume; decreasing the pressure causes a proportional increase in volume.
2. When pressure is held constant, increasing the temperature of a gas causes a proportional increase in volume; decreasing the temperature causes a proportional decrease in volume.
3. When the volume is held constant, increasing the temperature of a gas causes a proportional increase in pressure; decreasing the temperature causes a proportional decrease in pressure.

In this discussion of the effects of pressure on a gas, we have noted that the volume and the temperature of the gas are different AFTER the pressure has been changed. It is important to note, however, that a temperature change normally occurs in a gas WHILE the pressure is being changed. Compressing a gas raises its temperature; allowing a gas to expand lowers its temperature. As we will see, this fact is of importance in the refrigeration cycle.

MECHANICAL REFRIGERATION SYSTEMS

Various types of refrigerating systems are used for naval shipboard refrigeration and air conditioning. The most generally employed is the vapor compression cycle with reciprocating compressors. Vapor compression cycle refrigerating systems with centrifugal compressors as described in chapter 12 are sometimes used for air conditioning. Centrifugal units are generally used to cool a secondary refrigerant; brine for cargo refrigeration and fresh water for air conditioning application.

The STEAM-JET REFRIGERATION SYSTEM is used on some naval ships for air conditioning purposes. As shown in figure 11-1, the steam-jet plant consists of a flash tank, a booster ejector, a condenser, air ejectors, and the necessary pumps and piping. The flash tank (sometimes called the evaporator) is maintained under exceptionally high vacuum by the air ejector on some other vacuum producing device. As water is sprayed into the flash tank, part of each drop flashes into vapor and thereby cools the unvaporized portion of each drop to about 50°F or lower, depending upon the capacity of the unit. The vapor formed by this evaporation is removed or "pumped" to the condenser by the steam jet booster ejector. The cooled water falls to the bottom of the shell; it is then pumped to the cooling coils, and returned to the flash tank at a temperature of about 55°F.

The vapor compression cycle with reciprocating compressors using R-12 is used for

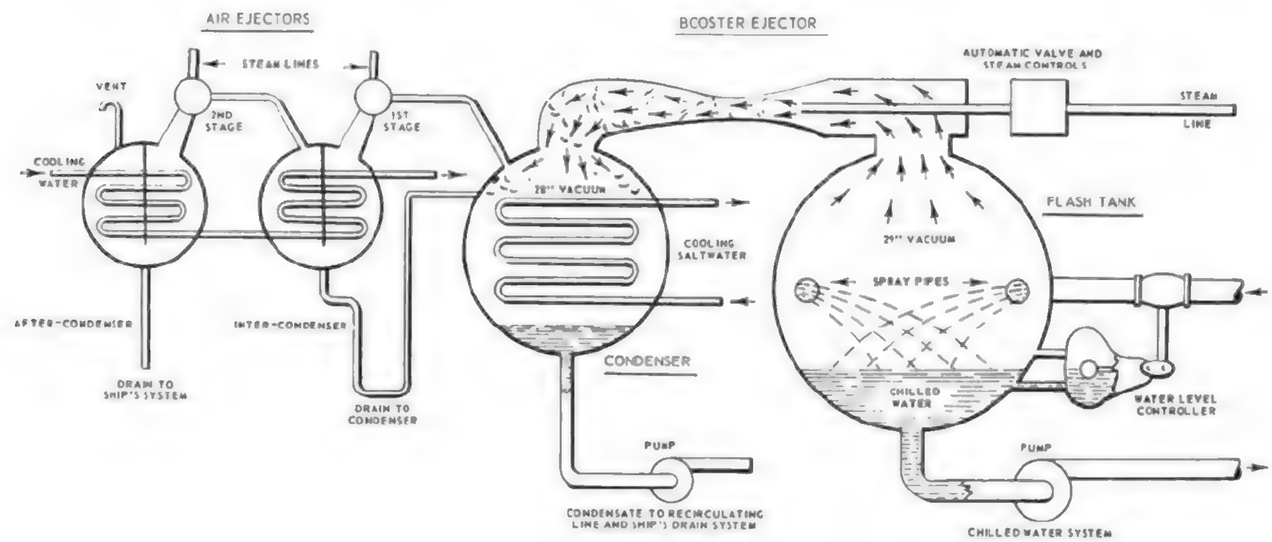


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Figure 11-1. — Steam-jet refrigeration system.

most naval refrigerating plants. Figure 11-2 gives a general idea of this type of refrigeration cycle. As you study this system, try to understand what happens to the refrigerant as it passes through each part of the cycle. In particular, be sure that you understand why the refrigerant changes from liquid to vapor and from vapor to liquid, and what happens in terms of heat because of these changes of state. It will be helpful to trace the refrigerant through its entire cycle, beginning with the thermostatic expansion valve.

Liquid refrigerant enters the expansion valve from the high pressure side of the system and passes through an orifice, which reduces the pressure of the refrigerant. Due to the reduction in pressure, the liquid refrigerant begins to boil and to flash into vapor.

From the thermostatic expansion valve, the refrigerant passes into the cooling coil (or evaporator). The boiling point of the refrigerant under the low pressure in the evaporator is about 20°F lower than the temperature of the space in which the cooling coil is installed. As the liquid boils and vaporizes, it picks up its latent heat of vaporization from the surroundings, thereby removing heat from the space. The refrigerant continues to absorb latent heat of vaporization until all the liquid has been vaporized. By the time the refrigerant is ready to leave the cooling coil, it has not only absorbed this latent heat of vaporization, but has also picked up some additional heat — that is, the vapor has become superheated. As a rule, the amount of superheat is 4° F to 12° F.

The refrigerant leaves the evaporator as a low pressure superheated vapor, having absorbed heat and thus cooled the space to the desired temperature. The remainder of the cycle is concerned with disposing of this heat and converting the refrigerant back into a liquid state so that it can again vaporize in the evaporator and thus again absorb the heat.

The low pressure superheated vapor is drawn out of the evaporator by the compressor, which also keeps the refrigerant circulating through the system. In the compressor cylinders, the refrigerant is compressed from a low pressure, low temperature vapor to a high pressure vapor, and its temperature rises accordingly.

The high pressure R-12 vapor is discharged from the compressor into the condenser. Here the refrigerant condenses, giving up its superheat (sensible heat) and its latent heat of vaporization to the ambient air in an air-cooled condenser or the cooling water in a water-cooled condenser. The refrigerant, still at high pressure, is now a liquid again.

From the condenser, the refrigerant flows into a receiver, which serves as a storage place for the liquid refrigerant in the system. From the receiver, the refrigerant goes to the thermostatic expansion valve, and the cycle begins again.

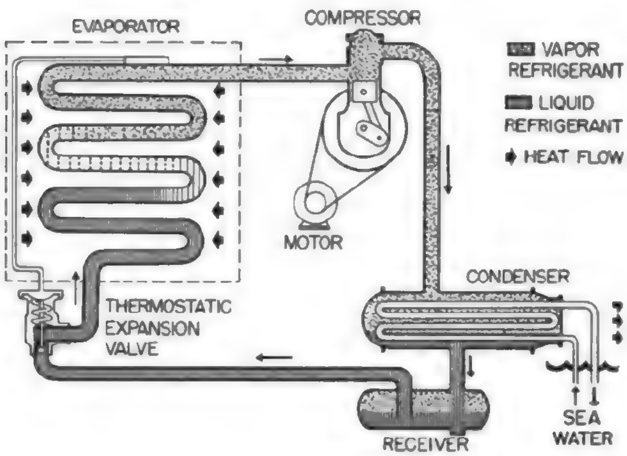

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Figure 11-2.—R-12 refrigeration cycle.

As you can see from this description of the compression cycle, this type of refrigeration system has two pressure sides. The LOW PRESSURE SIDE extends from the orifice of the thermostatic expansion valve up to and including the intake side of the compressor cylinders. The HIGH PRESSURE SIDE extends from the discharge valve of the compressor to the thermostatic expansion valve.

MAIN PARTS OF THE R-12 SYSTEM

The main parts of an R-12 refrigeration system are shown diagrammatically in figure 11-3. The primary components of the system are the thermostatic expansion valve, the evaporator, the compressor, the condenser, and the receiver. Additional equipment required to complete the plant includes piping, pressure gages, thermometers, various types of control switches and control valves, strainers, relief valves, sight-flow indicators, dehydrators, and charging connections. Figure 11-4 shows most of the components on the high pressure side of an R-12 system, as actually installed on board ship.

In the following discussion, we will deal with the R-12 system as though it had only one evaporator, one compressor, and one condenser. As you will see from figure 11-3 however, a refrigeration system may (and usually does) include more than one evaporator; and it may include additional compressor and condenser units.

Thermostatic Expansion Valve

The thermostatic expansion valve is essentially a reducing valve between the high pressure side and the low pressure side of the system. The valve is designed to regulate the rate at which the refrigerant enters the cooling coil in proportion to the rate of evaporation of the liquid refrigerant in the coil; the amount depends of course, on the amount of heat being removed from the refrigerated space.

A thermal control bulb for the thermostatic expansion valve is clamped to the cooling coil, near the outlet. The bulb contains R-12. Control tubing connects the bulb with the area above the diaphragm in the thermostatic expansion valve. When the temperature at the control bulb rises, the R-12 expands and transmits a pressure to the diaphragm; this causes the diaphragm to be moved downward, thus opening the valve and allowing more refrigerant to enter the cooling coil. When the temperature at the control bulb falls, the pressure above the diaphragm is decreased and the valve tends to close. Thus, the temperature near the evaporator outlet controls the operation of the thermostatic expansion valve.

Evaporator

The evaporator consists of a coil of copper tubing installed in the space to be refrigerated. Figure 11-5 illustrates some of this tubing. As mentioned before, the liquid R-12 enters the tubing at a very much reduced pressure and with, therefore, a very much lowered boiling point. In passing through the expansion valve, part of the refrigerant boils and vaporizes, due to the reduced pressure, and the remaining liquid refrigerant is cooled to its boiling point. Then, as the refrigerant passes through the evaporator, the heat flowing to the coil from the surrounding air causes the rest of the liquid refrigerant to boil and vaporize. After the refrigerant has absorbed its latent heat of vaporization (that is, after it is entirely vaporized), the refrigerant continues to absorb heat until it becomes superheated by about 10° F. The amount of superheat is determined by the amount of liquid refrigerant admitted to the

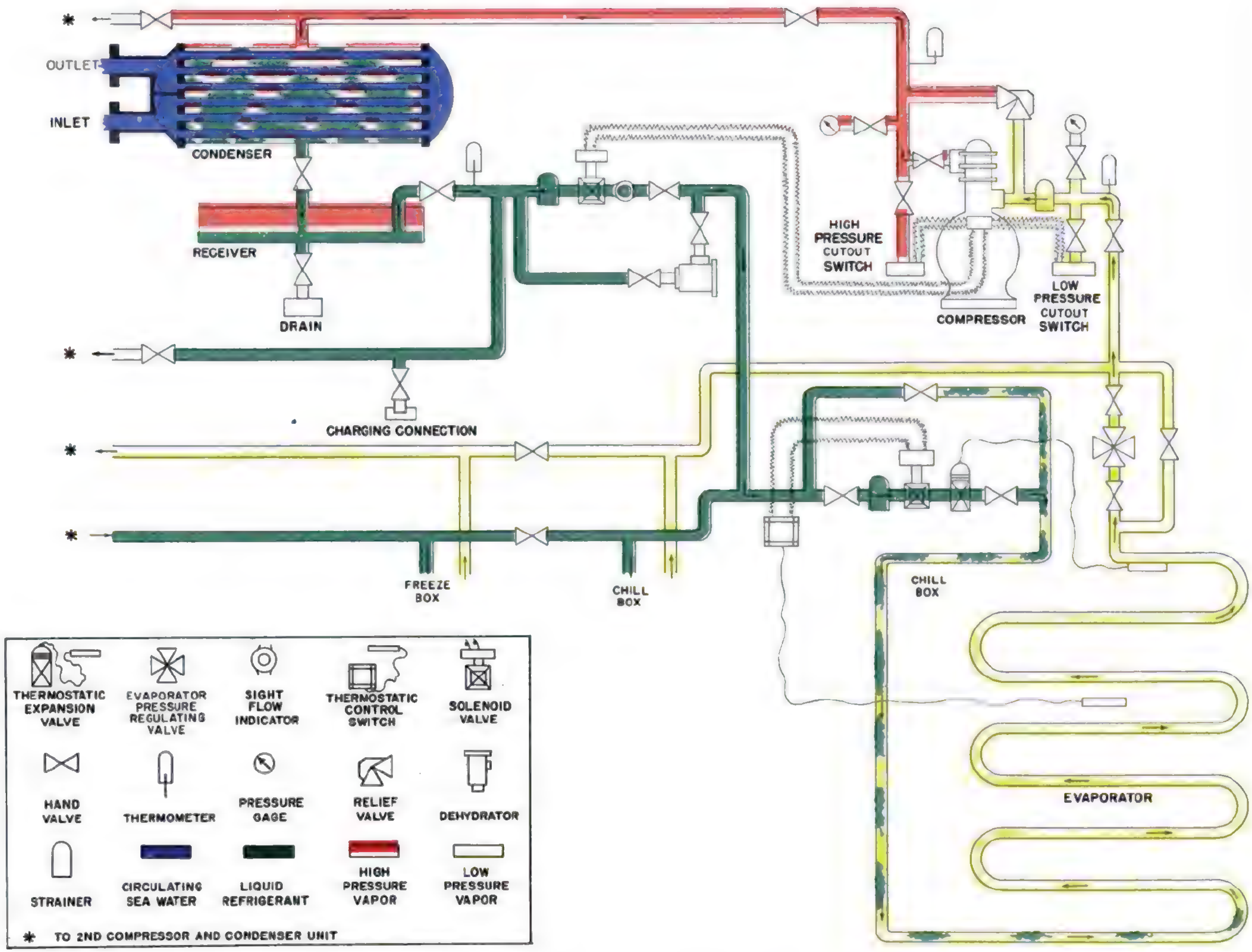

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Figure 11-3. — Diagram of an R-12 refrigeration system.

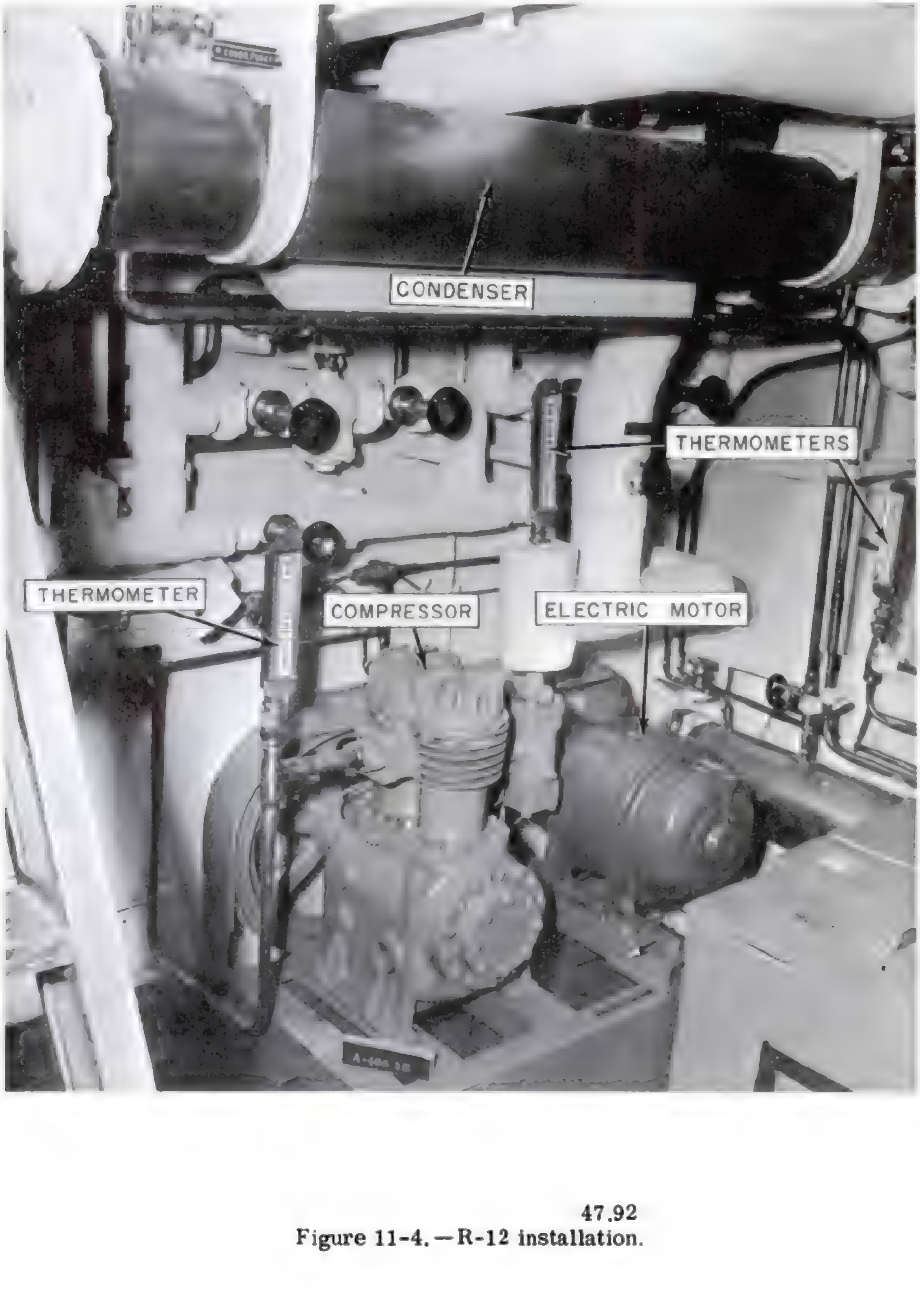

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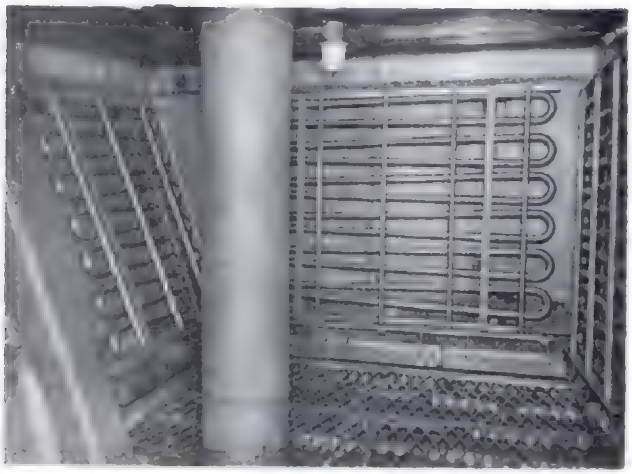
Figure 11-4.—R-12 installation.



47.93
Figure 11-5.—Evaporator tubing.

evaporator; and this, in turn, is controlled by the spring adjustment of the thermostatic expansion valve. A temperature range of 4° to 12° F of superheat is considered desirable because it increases the efficiency of the plant and because it evaporates all of the liquid, thus preventing liquid carryover into the compressor.

Compressor

The compressor in a refrigeration system is essentially a pump. It is used to pump heat "uphill" from the cold side to the hot side of the system.

The heat absorbed by the refrigerant in the evaporator must be removed before the refrigerant can again absorb latent heat. The only way in which the vaporized refrigerant can be made to give up the latent heat of vaporization that it absorbed in the evaporator is by cooling and condensing it. In view of the relatively high temperature of the available cooling medium, the only way to make the vapor condense is by first compressing it.

The vapor drawn into the compressor is at very low pressure and very low temperature. In the compressor, both the pressure and the temperature are raised. Since an increase in pressure causes a proportional rise in temperature, and since the condensation point of any vapor is dependent upon the pressure, raising the pressure of the vaporized refrigerant provides a condensation temperature high enough to permit the use of sea water as the condensing and cooling medium. The compressor raises the pressure of the vaporized refrigerant sufficiently high to permit condensation to take place in the condenser.

In addition to this primary function, the compressor also serves to keep the refrigerant circulating and to maintain the required pressure difference between the high pressure side and the low pressure side of the system.

Many different types of compressors are used in refrigeration systems. The designs of compressors vary depending upon the application of the refrigerants used in the system. Figure 11-6 shows a motor-driven, single acting, two-cylinder, reciprocating compressor such as is commonly used in naval refrigeration plants.

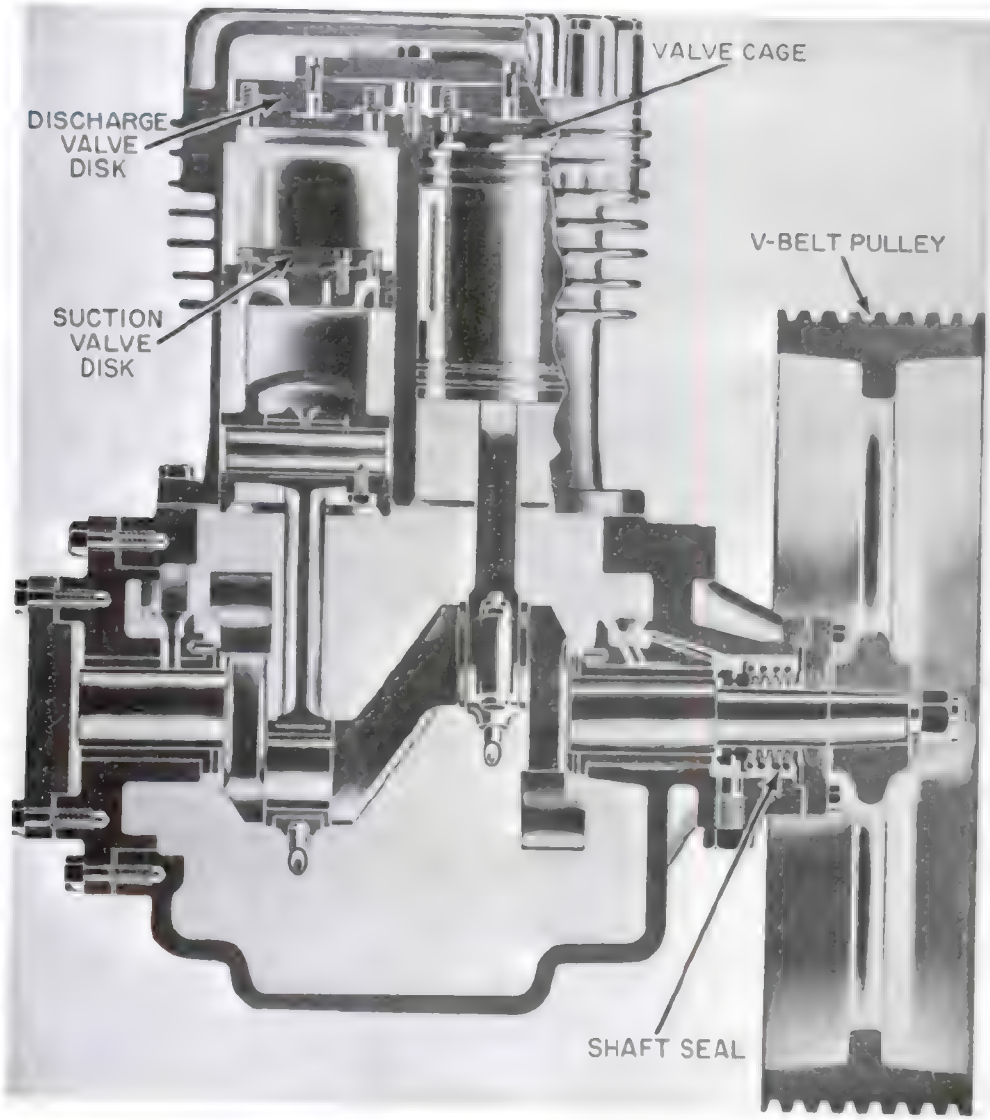
Compressors used in R-12 systems may be lubricated either by pressure lubrication or by splash lubrication. Splash lubrication, which depends upon maintaining a fairly high oil level in the compressor crankcase, is usually satisfactory for smaller compressors. High speed, or large capacity, compressors use pressure lubrication systems.

Condenser

The compressor discharges the high pressure, high temperature refrigerant vapor to the condenser, where it flows around the tubes through which sea water is being pumped. As the vapor gives up its superheat (sensible heat) to the sea water, the temperature of the vapor drops to the condensation point. As soon as the temperature of the vapor drops to its boiling or condensing temperature at the existing pressure, the vapor condenses, giving off its latent heat of vaporization in the process. The refrigerant, now in liquid form, is subcooled slightly below its boiling point (condensation point) at this pressure to ensure that it will not flash into vapor.

A water-cooled condenser for an R-12 refrigeration system is shown in figure 11-7. Circulating water is obtained through a branch connection from the firemain, or by means of an individual pump taking suction from the sea. The purge connection shown in figure 11-7 is on the refrigerant side; it is used to remove air and other noncondensable gases that are lighter than the R-12 vapor.

Most condensers used for naval refrigeration plants are of the water-cooled type. However,



47.94
Figure 11-6.—Reciprocating compressor.

it should be mentioned that some small units have air-cooled condensers. These consist of tubing with external fins to increase the heat transfer surface. Most air-cooled condensers have fans to ensure positive circulation of air around the condenser tubes.

Receiver

The receiver, shown in figure 11-8, acts as a temporary storage space and surge tank for the liquid refrigerant which flows from the condenser. The receiver also serves as a vapor seal, to prevent the entrance of vapor into the liquid line to the expansion valve. Receivers may be constructed for either horizontal or vertical installation.

Accessories

In addition to the five main components just described, a refrigeration system requires a number of controls and accessories. The most important of these will be described briefly.

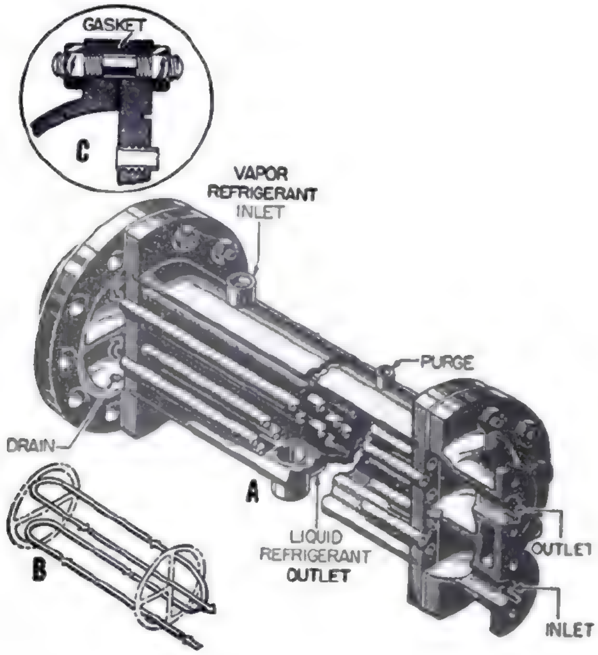


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Figure 11-7.—Water-cooled condenser for R-12 refrigeration system. A. Cutaway view. B. Water-flow diagram. C. Arrangement of heat joint.

A DEHYDRATOR, or dryer, is placed in the liquid refrigerant line between the receiver and the thermostatic expansion valve. In older installations, bypass valves allow the dehydrator to be cut in or out of the system. In newer installations, the dehydrator is installed in the liquid refrigerant line without any bypass arrangement. A MOISTURE INDICATOR is either located in the liquid refrigerant line or built into the dehydrator. A dehydrator is shown in figure 11-9. The moisture indicator indicates the presence of moisture by means of a chemically treated element which changes color on an increase of moisture in the refrigerant. The color change is reversible and will change back to a DRY reading when the moisture is removed from the refrigerant. Excessive moisture or water will damage the moisture indicator element and turn it gray.

A SOLENOID VALVE is installed in the liquid line leading to each evaporator. Figure 11-10 shows a solenoid valve and the thermostatic control switch that operates it. The thermostatic control switch is connected by long flexible tubing to a thermal control bulb which is located in the refrigerated space. When the temperature in the refrigerated space drops to the desired point, the thermal control bulb causes the thermostatic control switch to open, thereby closing the solenoid valve and

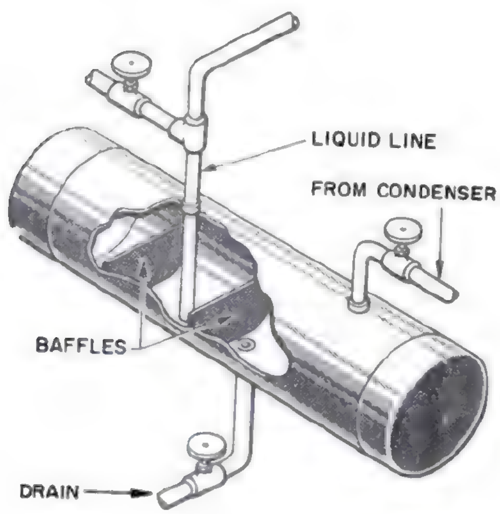

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Figure 11-8.—Receiver.

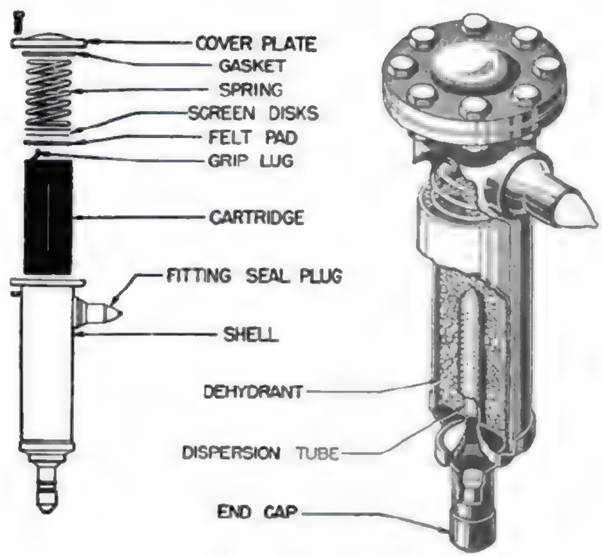

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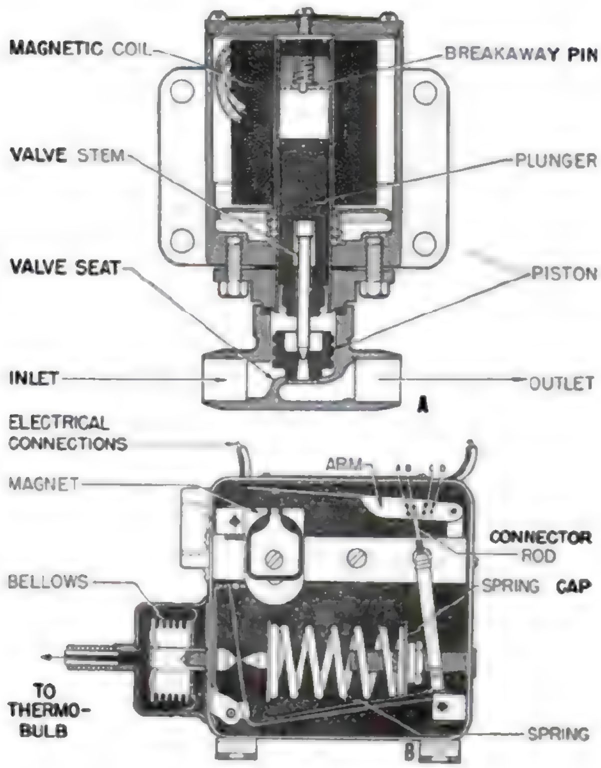
Figure 11-9.—Refrigerant dehydrator.



47.93
Figure 11-10.—Solenoid valve and thermostatic control switch.

shutting off all flow of liquid refrigerant to the thermostatic expansion valve. When the temperature in the refrigerated space rises above the desired point, the thermostatic control switch closes, the solenoid valve opens, and liquid refrigerant once again flows to the thermostatic expansion valve.

The solenoid valve and its related thermostatic control switch serve to maintain the proper temperature in the refrigerated space. If the thermostatic expansion valve controls the amount of refrigerant admitted to the evaporator, why is the solenoid valve necessary? Actually, the solenoid valve is not necessary on units having only one evaporator. In systems having more than one evaporator, where there is wide variation in load, the solenoid valve provides the additional control required to prevent the spaces from becoming too cold at light loads.

In addition to the solenoid valve installed in the line to each evaporator, a large refrigeration plant usually has a main liquid line solenoid valve installed just after the receiver. If the compressor stops for any reason except normal suction pressure control, the main liquid solenoid valve closes and prevents liquid refrigerant from flooding the evaporator and flowing to the compressor suction. Extensive damage to the compressor can result if liquid is allowed to enter the compressor suction.

Whenever several refrigerated spaces of varying temperatures are to be maintained by one compressor, an EVAPORATOR PRESSURE REGULATING VALVE is installed at the outlet of each evaporator EXCEPT the evaporator in the space in which the lowest temperature is to be maintained. The evaporator pressure regulating valve is set to keep the pressure in the coil from falling below the pressure corresponding to the lowest evaporator temperature desired in that space.

Suction pressure regulating valves may be installed in the suction line at the outlet of the evaporator where minimum temperature must be maintained as in certain types of water cooler applications or where high humidities are desired, as in fruit and vegetable rooms, or where two or more spaces are maintained at different temperature levels from a single compressor unit. (Pressure regulating valves are designed to maintain a substantially constant pressure within the cooling coil higher than the suction pressure downstream and independent of suction pressure fluctuations.) Valve adjustment is obtained by compression of the adjusting spring to a point where a predetermined coil pressure is established. The automatic operation is maintained by diaphragm balance resulting from small fluctuation in coil pressures permitting positioning of the valve seat to adjust the refrigerant flow.

Suction pressure regulating valves function to decrease the temperature difference which would otherwise exist between the compartment temperature and the surface of the cooling coils. Since the amount of heat which can be transferred into the evaporating refrigerant is directly proportional to the temperature difference, the employment of suction pressure regulating valves requires the provision of more coil surface in a given compartment than would be otherwise necessary.

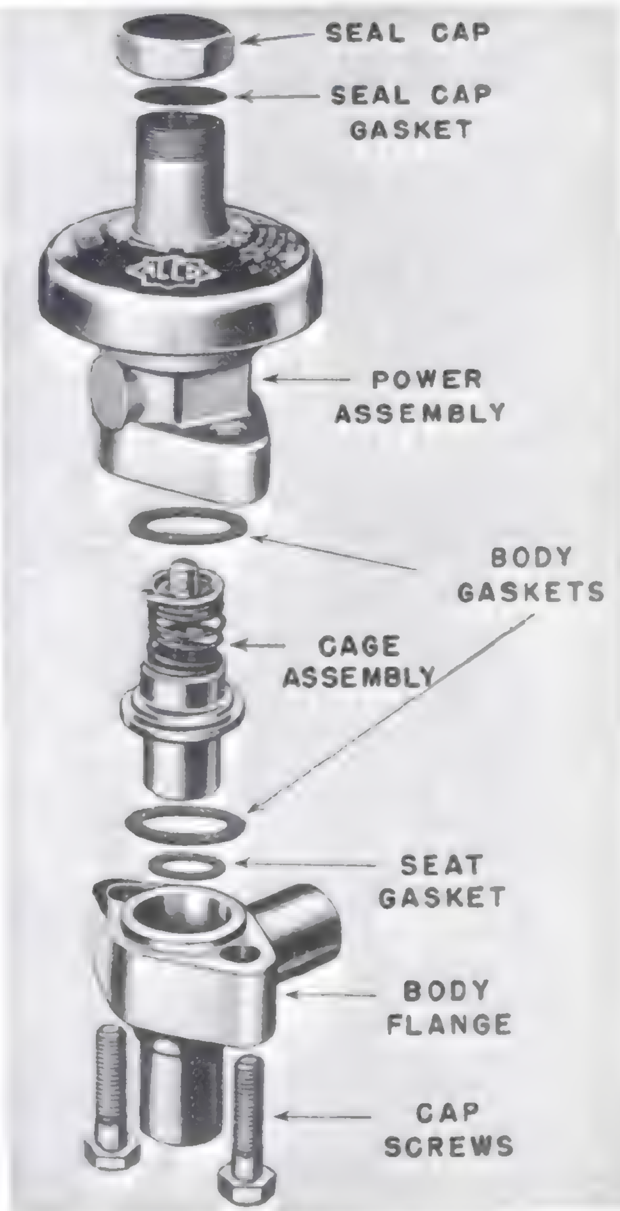
Suction pressure regulating valves are ADJUSTED by changing the pressure exerted by an auxiliary spring against the valve disk.

For a given setting the valve maintains a substantially constant pressure in the cooling coil regardless of changes in the compressor

suction pressure, provided that the suction pressure is about 4 psi or more lower than that which the regulator is set to maintain in the coil. Adjustment to increase the spring pressure tending to close the valve increases the evaporating pressure and vice versa. A test gage is temporarily connected to the cooling coil side of the valve when adjustment is to be made.

The pressure setting for any individual application is dependent on coil design and the amount of coil surface available. In general, settings are not critical where the same refrigerant circuit is also controlled by a solenoid valve except that the pressure setting must be maintained sufficiently low to provide a temperature differential between the refrigerant evaporating temperature and the compartment temperature. Where temperature and humidity control depend on the pressure regulating valve, the setting must be sufficiently high to permit the control desired, keeping in mind the temperature differential required for satisfactory coil operation. Where the medium being cooled is water, as in process and drinking-water coolers, the setting of the suction pressure regulating valve is VERY CRITICAL and, if improperly or hastily adjusted, may cause derangement. A change in pressure setting of 1 pound will appreciably change the temperature of the delivered water. Too low a pressure setting will result in an almost immediate freezing of the water in the cooler with possible rupture. Consequently, adjustment of this valve in a water-cooler application should be very carefully made. Turn the adjusting screw only one-eighth turn at a time and take frequent samples of delivered water to check the temperature.

Figure 11-11 shows an exploded view of a typical valve which demonstrates the ease of disassembly for repair or replacement of the parts without disturbing soldered piping joints. Dirt or foreign matter under the seat or in moving parts can cause erratic operation.



87.70
Figure 11-11.—Exploded view of typical suction pressure regulating valve.

The LOW PRESSURE CUTOUT SWITCH, or suction pressure control switch, is the control that causes the compressor to go on or off, as required for normal operation of the refrigeration plant. This switch is located on the suction side of the compressor, and is actuated by pressure changes in the suction line. When the solenoid valves in the lines to the various evaporators are closed, so that the flow of refrigerant to the evaporators is stopped, the pressure of the vapor in the compressor suction line drops quickly. When the suction pressure has dropped to the desired pressure, the low pressure cutout switch causes the compressor motor to stop. When the temperature in the refrigerated spaces has risen enough to operate one or more of the solenoid valves,

refrigerant is again admitted to the cooling coils, and the compressor suction pressure builds up again. At the desired pressure, the low pressure cutout switch closes, starting the compressor again and repeating the cycle.

A HIGH PRESSURE CUTOUT SWITCH is connected to the compressor discharge line to protect the high pressure side of the system against excessive pressures. The design of this switch is essentially the same as that of the low pressure cutout switch, however, the low pressure cutout switch is made to CLOSE when the suction pressure reaches its upper normal limit, whereas the high pressure cutout switch is made to OPEN when the discharge pressure is too high. The high pressure switch is normally set to stop the compressor when the pressure reaches 160 psi and to start it again when the pressure drops to 140 psi. As mentioned before, the low pressure cutout switch is the compressor control for normal operation of the plant; the high pressure cutout switch, on the other hand, is a safety device only and does not have control of compressor operation under normal conditions.

An OIL FAILURE SWITCH is provided where high speed compressors are used. This switch is designed to prevent operation of the compressor in the event of low oil pressure. The switch is installed with one bellow connected to the oil pressure on the discharge of the compressor oil pump and the other to the compressor suction refrigerant pressure. The switch is set to open the electrical circuit and stop the compressor when the oil pressure drops to 5 psi above compressor crankcase pressure and to close the electrical circuit and start the compressor when the oil pressure reaches 10 psi above the crankcase pressure.

In order that the compressor can be started after it has been stopped and the contacts of the oil failure switch have opened, a time delay mechanism is used with the compressor motor starter. The time delay switch will open 10 to 30 seconds after the compressor motor has been started. The oil pressure normally will be built-up in this time interval so that the oil pressure switch will have made contact to keep the compressor motor electrical circuit energized after the time delay switch opens. If the oil pressure has not built-up within about 30 seconds after the compressor is started, the contacts of the oil pressure differential switch will not have closed, and the compressor will stop because the time delay relay switch is open.

A SPRING LOADED RELIEF VALVE is installed in the compressor discharge line as an additional precaution against excessive pressures. The relief valve is set to open at about 225 psi; therefore, it functions only in case of failure or improper setting of the high pressure cutout switch. If the relief valve opens, it discharges high pressure vapor to the suction side of the compressor.

A WATER REGULATING VALVE is installed to control the quantity of circulating water flowing through the refrigerant condenser. The water regulating valve is actuated by the refrigerant pressure in the compressor discharge line; this pressure acts upon a diaphragm (or, in some valves, a bellows arrangement) which transmits motion to the valve stem. The primary function of the water regulating valve is to maintain a constant refrigerant condensing pressure. Basically two variable conditions exist, the amount of refrigerant to be condensed and changing water temperatures. The valve maintains a constant refrigerant condensing pressure by controlling the water flow through the condenser. By sensing the refrigerant pressure it permits only that quantity of water through the condenser that is necessary to condense the amount of refrigerant vapor coming from the compressor. The quantity of water required to condense a given amount of refrigerant varies with the water temperature. Thus, the flow of cooling water through the condenser is automatically maintained at the rate actually required to condense the refrigerant under varying conditions of load and temperature.

A WATER FAILURE SWITCH is provided to stop the compressor in the event of failure of the circulating water supply. This is a pressure-actuated switch, generally similar to the low pressure cutout switch and the high pressure cutout switch previously described. If the water failure cutout switch should fail to function, the refrigerant pressure in the condenser would quickly build up to the point where the high pressure switch would function.

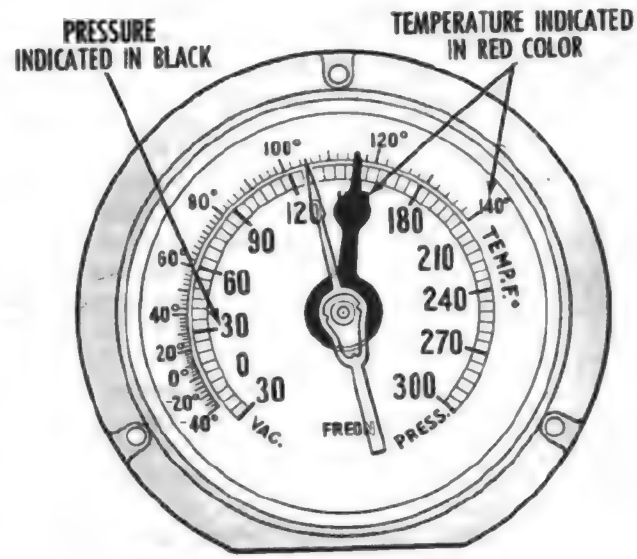
Because of the solvent action of R-12, any particles of grit, scale, dirt, and metal that the system may contain are very readily circulated through the refrigerant lines. To avoid damage to the compressor from such foreign matter, a STRAINER is installed in the compressor suction connection.

In addition, a LIQUID STRAINER of the type shown in figure 11-12 is installed in the liquid line leading to each evaporator; these strainers serve to protect the solenoid valves and the thermostatic expansion valves.

A number of PRESSURE GAGES and THERMOMETERS are used in refrigeration systems. Figure 11-13 shows a compound refrigerant gage. The temperature markings on this gage show the boiling point (or condensing point) of the refrigerant at each pressure; the gage cannot measure temperature directly. The short pointer (red in color) is a stationary pointer that can be set manually to indicate the maximum working pressure.

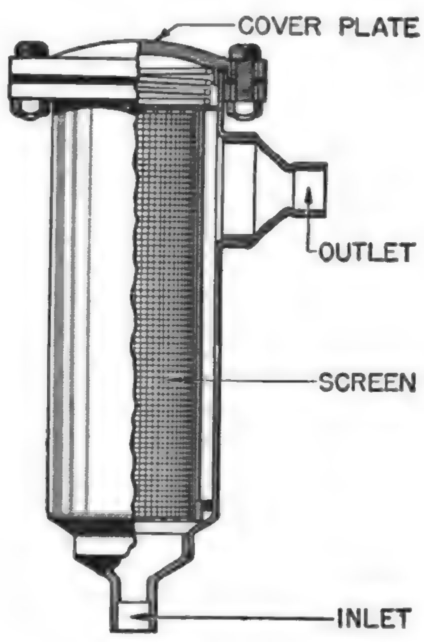
A water pressure gage is installed in the circulating water line to the condenser, to give visual indication of failure of the circulating water supply.

Standard thermometers of appropriate range are provided for the refrigerant system.



47.102
Figure 11-13.—Compound R-12 pressure gage.

REFRIGERANT PIPING in modern naval installations is made of copper. Copper is good for this purpose because (1) it does not become corroded by refrigerants; (2) the internal surface of the tubing is smooth enough to minimize friction; and (3) copper tubing is easily shaped to meet installation requirements.

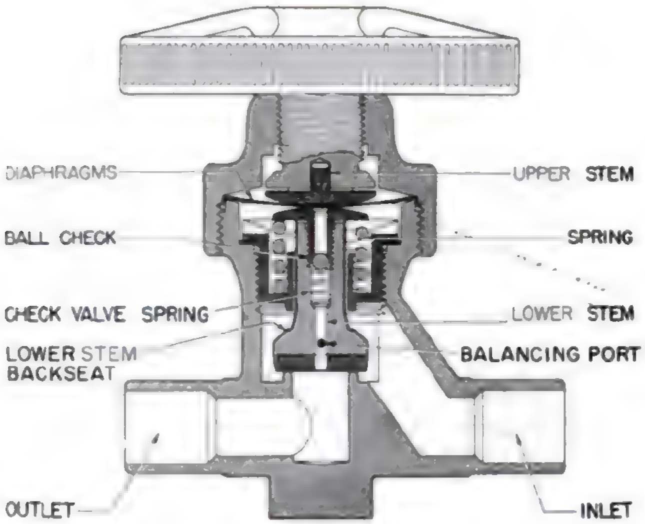


47.101
Figure 11-12.—Strainer for liquid refrigerant.

Nearly all hand-operated valves in large refrigeration systems are PACKLESS VALVES of the type shown in figure 11-14. In this type of valve, the upper part of the valve is sealed off from the lower part by a diaphragm. An upward-seating ball check in the lower valve stem makes it possible for the spring to lift the lower stem regardless of pressure differences developed while the valve was closed. Thus, the valve will operate properly regardless of direction of flow. By backseating the valve, the diaphragm can be changed without placing the system or unit out of operation.

OPERATING PROCEDURES FOR AN R-12 SYSTEM

Learning how to do all of the tasks related to refrigeration system operation will require a good deal of practical experience and attentive observation of the procedures followed by those qualified in refrigeration system operation and maintenance. As a Machinist's Mate, your initial responsibility will probably include checking temperatures and pressures, maintaining the plant operating log, detecting symptoms of faulty operation, and checking conditions in the spaces or units being cooled.



47.103
Figure 11-14.—Packless valve for refrigeration system.

The intervals of time between plant inspections will vary depending upon the purpose for which the plant is used. The temperatures and pressures throughout the system and the oil level in the compressor crankcase are checked and the results recorded every two hours unless watch-standing instructions specify otherwise. The results of these checks can be used to determine whether the plant is operating properly. One of the best methods for checking plant operation is to compare the existing temperatures and pressures with those recorded during a period when the plant was known to be operating properly, under conditions similar to the present conditions.

The following information on operating procedures applies to refrigeration systems in general.

1. Open the compressor discharge valve; open all stop valves in the circulating water supply and in the discharge lines for the condenser.
2. Open the condenser refrigerant outlet valve and open the thermal expansion stop valves on the chill and freeze boxes.
3. Start all air circulating fans. On water cooling applications (soda fountains, drinking water coolers, and air conditioning water chillers), admit the water to be cooled, and purge the water circuit of air.
4. If water is taken from the firemain, make certain that the pressure-reducing valve ahead of the water regulating valve is adjusted to provide a water pressure of 35 psi or less ahead of the water regulating valve.
5. When no pressure-reducing valve is installed, regulate the firemain connection stop valve manually so that the required water pressure ahead of the water regulating valve is maintained.
6. When an individual circulating pump is used to supply condenser circulating water, be sure that any valves which permit transmission of pump discharge pressure to the water failure switch are open.
7. If the compressor unit is equipped with an air-cooled condenser, make certain that the air flow passages to the condenser are unobstructed, and that the air circulating fans are clear.
8. Open the compressor discharge-line valve, the stop valve in the line connecting the condenser and the liquid receiver, and the main liquid-line valve.

Starting the Compressor

Too much stress cannot be placed on the need for thoroughness and care at the time the compressor is started. Bent crankshafts, distorted valves, and blown gaskets are a few of the casualties which may occur if proper procedures and applicable precautions are not followed. After accomplishing or checking the items listed under the posted prestarting instructions, proceed as follows:

1. Set the AUTOMATIC-MANUAL selector switch in the MANUAL position.
2. Close the maintaining-contact START button in the pump control circuit to prepare the pump motor for starting.
3. Close the momentary-contact START switch in the compressor control circuit to start the pump motor which also energizes the main line solenoid valve circuit.

As the pump circulates the water, the water failure switch closes automatically and completes the circuit of the compressor-motor contactor coil. When this circuit is closed, the compressor motor starts. In installations where a pump motor and a pump control circuit are not installed, closing the momentary-contact START switch energizes the compressor control circuit and starts the compressor motor.

4. Start and stop the motor and compressor several times by manual control, to check their operating condition; then, stop the compressor and check the oil level.

5. After it has been determined that the motor and the compressor are in operating condition, crack the suction stop valve and set the controls on AUTOMATIC. This arrangement will eliminate the possibility of the pressure in the system from decreasing below that of the atmosphere and drawing air into the compressor.

Open the compressor suction valve slowly, with the compressor running, so as to limit the quantity of suction gas handled by the compressor.

The suction gage should be watched as the compressor suction valve is opened to ensure that the suction pressure is within the limits of the automatic control low pressure suction setting. The valve should be opened gradually, at a rate so that there will be neither a rapid fluctuation in suction pressure nor a rapid drop of pressure in the compressor crankcase. This will prevent the rapid boiling off of refrigerant from the oil and the carrying of oil into the system. Unusual noise or knocking in the compressor and frosting of crankcase or suction valve are indications of liquid refrigerant being drawn into the compressor.

6. If lubrication of the compressor is by forced feed, check the pressure on the oil pressure gage.

Unless specific instructions indicate otherwise, the oil pressure should be between 15 and 30 psi above the compressor suction pressure within a few seconds after the compressor is started. If the compressor is designed for automatic capacity control, oil pressure of 50 to 60 psi above suction pressure is required.

7. Make certain that the proper quantity of circulating water is flowing through the condenser before the compressor discharge pressure reaches 125 psi.

8. Open the receiver outlet valve and the main solenoid outlet valve.

In systems not equipped with water regulating valves, normal operating conditions generally produce condensing pressures of less than 125 psi, since the condensing water temperature is usually less than 85°F. In systems equipped with water regulating valves, the valves should be adjusted to maintain the condensing pressure at 125 psi. When the valves are so adjusted, the quantity of cooling water required decreases rapidly with decreasing circulating water temperatures. In systems equipped with air-cooled condensers, condensing pressures may exceed 125 psi when the temperature of the surrounding air is higher than normal.

Operating An R-12 Plant In Automatic

After the prescribed operating pressures and temperatures have been established with the selector switch set in the AUTOMATIC position, the suction-pressure control is so connected by electrical means, that it starts and stops the compressor automatically, on the basis of load conditions. If the automatic control valves and switches are in proper adjustment, the operation of the plant, after proper starting, will be entirely automatic.

When the selector switch is set for automatic operation, the closing of the water failure switch, the high pressure switch, or the low pressure switch through automatic operation will energize their respective circuits. Other control devices require the intervention of an operator before the compressor can be restarted. Some high pressure switches are provided with manual reset devices which must be reset by the operator after the switches have been opened by excessive pressure.

Some installations are designed so that the supply of condenser cooling water is available either from a centrifugal pump or from the fire and flushing main directly. If cooling water is obtained from the fire and flushing main instead of from the pump, the pump controller switch is opened manually. The water failure switch remains closed regardless of the source of condenser cooling water.

Securing The Compressor

If a compressor is to be secured for only a short period, it is not necessary to pump down the system. The compressor however, must be pumped down. To do this, first close the compressor suction valve slowly, to prevent too rapid a reduction in crankcase pressure. Then allow the compressor to run until it is stopped by the low pressure control switch; push the STOP button on the motor-control panel. Next, close the compressor discharge shutoff valve; shut off the water supply to the condensers. Finally, close the main liquid valve after the receiver.

If a refrigeration system is to be secured for an extended period, the system must be pumped down. The pumping-down procedure involves pumping most of the R-12 out of the coils of the evaporator, and storing the refrigerant in the receiver. If the quantity of liquid refrigerant contained in the system is in excess of the capacity of the receiver, the surplus liquid must be drawn off into refrigerant drums.

Notes On Compressor Operation

An R-12 compressor should not remain idle for an extended period of time. When two or more compressors are installed for a particular plant, the compressors should be operated alternately so that the total operating time on each of the compressors is approximately the same. An idle compressor should be operated at least once a week.

Only one compressor should serve a cooling coil circuit. When compressors are operated in parallel on a common cooling coil circuit, lubricating oil may be transferred from one compressor to another. Such transfer of oil may result in serious damage to all compressors on the circuit.

Operating Log

The operating record of a refrigeration system must be maintained by the men on watch. The information recorded in the operating log serves as a guide to the condition of the plant. Figure 11-15 shows a daily operating log for a refrigeration system.

MAINTENANCE OF R-12 SYSTEMS

As a Machinist's Mate, you will do some of the maintenance jobs required to keep a refrigerating plant operating efficiently. In order for you to perform your share of the required maintenance of a refrigerating system, you must be familiar with the proper procedures for the following jobs: defrosting the cooling coils, pumping down a system and checking for noncondensable gases, purging a system of noncondensable gases, using a halide torch to test for refrigerant leaks, checking compressor oil, taking care of V-belts, and setting and adjusting refrigeration system controls and safety devices. Most of these maintenance items are covered by the Planned Maintenance System and will be scheduled accordingly. Figure 11-16 is an example of a CVA's maintenance schedule for refrigeration and air conditioning plants.

Defrosting of Cooling Coils

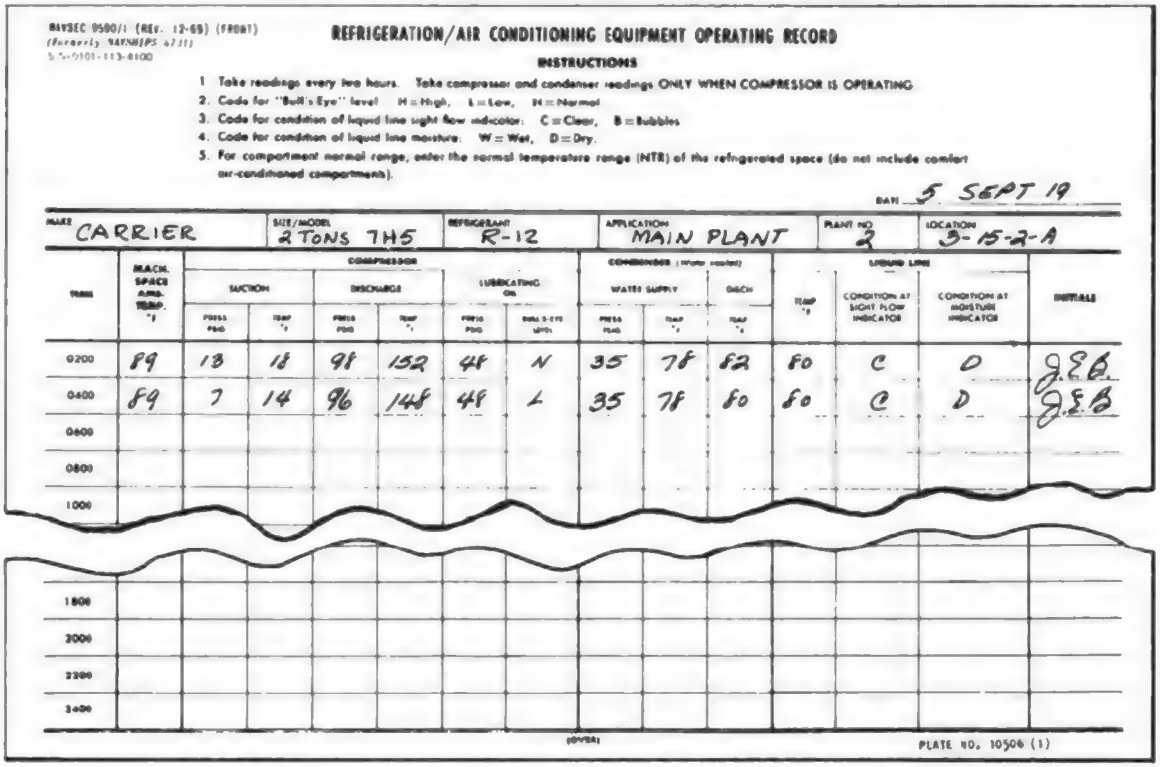
The cooling coils should be defrosted as often as necessary to maintain the effectiveness of the cooling surface. Excessive accumulations of frost on the coils will result in reduced cooling capacity, low compressor-suction pressure, and a tendency for the compressor to short cycle. The maximum permissible time interval between defrosting operations depends on many factors, such as refrigerant evaporating temperature, free-moisture content of supplies placed in the refrigerated space, temperature of refrigerated spaces, frequency of opening of cold-storage compartment doors, and atmospheric humidity. In the average cold-storage refrigeration installation it is good practice to defrost cooling coils before the average frost thickness reaches 3/16 inch. This is not a hard and fast rule, however; sometimes the frost layer may become appreciably thicker without seriously interfering with plant operation. At other times it may be necessary to defrost more often to maintain satisfactory operation of the plant and proper compartment temperature.

The most COMMON METHOD OF DEFROSTING a cooling coil in the average refrigeration installation is (1) to shut off the supply of R-12 to the coil to be defrosted, by closing the liquid-line stop valve ahead of the expansion valve; and (2) to permit the temperature in the compartment to rise above 32° F, by leaving the entrance door open. The frost will melt off the coils or may be easily brushed off. Since the cooling coils are made of tinned copper or galvanized steel tubing, care should be taken not to damage the evaporator coil if a scraper is used to remove frost.

Most installations now in use are provided with HOT-GAS DEFROSTING lines to facilitate defrosting where compartment temperatures are maintained at 32° F or less. The principal advantage of hot-gas defrosting is that this process permits defrosting of the freeze room coils while the rest of the plant operates normally.

In the following paragraphs, defrosting procedures will refer only to freeze room coils.

A hot-gas defrosting line leads from the compressor discharge piping to the tail-coil of the freeze room cooling coil. The hot-gas line



NAVSEC 9590/1 (REV. 12-69) (FRONT)
(Formerly NAVSHIPS 4731)
S/N 0101-113-4100

REFRIGERATION/AIR CONDITIONING EQUIPMENT OPERATING RECORD

INSTRUCTIONS

1. Take readings every two hours. Take compressor and condenser readings ONLY WHEN COMPRESSOR IS OPERATING
2. Code for "Bull's-Eye" level H = High, L = Low, N = Normal
3. Code for condition of liquid line sight flow indicator: C = Clear, B = Bubbles
4. Code for condition of liquid line moisture: W = Wet, D = Dry.
5. For compartment normal range, enter the normal temperature range (NTR) of the refrigerated space (do not include comfort air-conditioned compartments).

DATE 5 SEPT 19

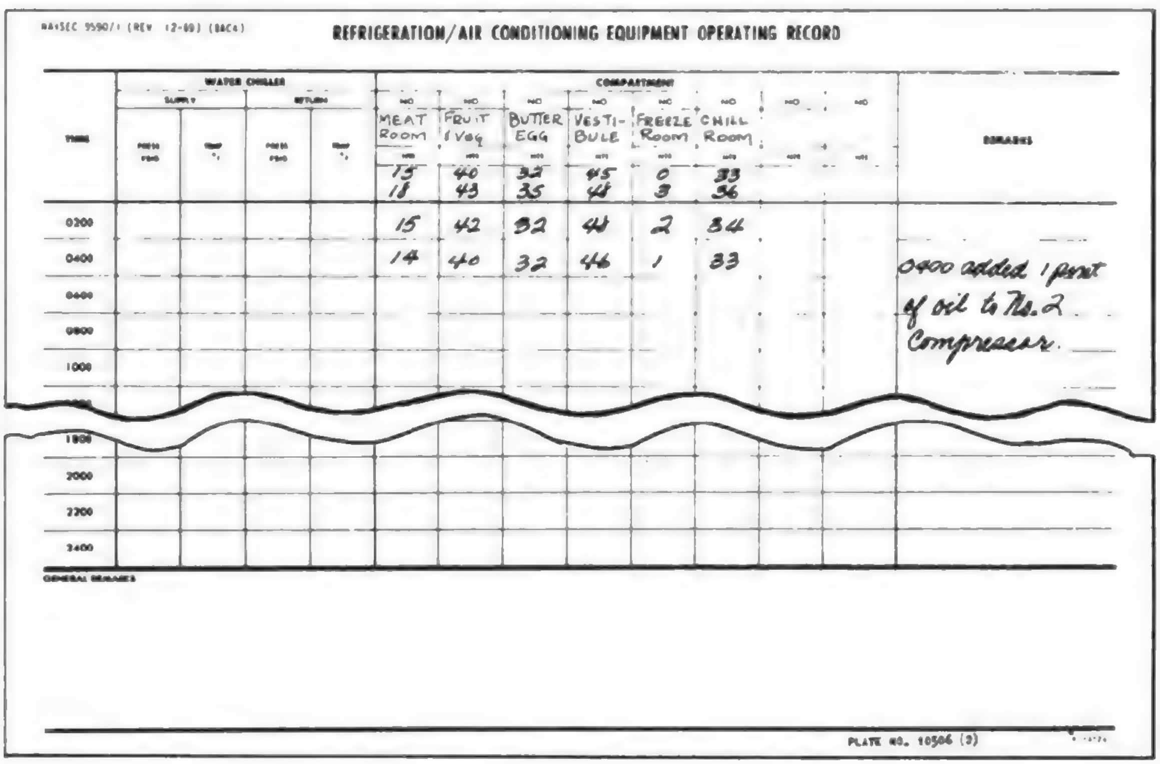
MAKE	SIZE/MODEL	REFRIGERANT	APPLICATION	PLANT NO	LOCATION
CARRIER	2 TONS 7H5	R-12	MAIN PLANT	2	3-15-2-A

TIME	MACH. SPACE AMB. TEMP. °F	COMPRESSOR SUCTION PRESS PSIG	SUCTION TEMP °F	DISCHARGE PRESS PSIG	DISCHARGE TEMP °F	LUBRICATING OIL PRESS PSIG	LUBRICATING OIL BULL'S-EYE LEVEL	CONDENSER (Water cooled) WATER SUPPLY PRESS PSIG	WATER SUPPLY TEMP °F	DISCH TEMP °F	LIQUID LINE TEMP °F	CONDITION AT SIGHT FLOW INDICATOR	CONDITION AT MOISTURE INDICATOR	INITIALS
0200	89	13	18	98	152	48	N	35	78	82	80	C	D	J.E.B.
0400	89	7	14	96	148	48	L	35	78	80	80	C	D	J.E.B
0600														
0800														
1000														
1800														
2000														
2200														
2400														

(OVER)

PLATE NO. 10506 (1)

A



NAVSEC 9590/1 (REV. 12-69) (BACK)

REFRIGERATION/AIR CONDITIONING EQUIPMENT OPERATING RECORD

TIME	WATER CHILLER SUPPLY PRESS PSIG	SUPPLY TEMP °F	RETURN PRESS PSIG	RETURN TEMP °F	COMPARTMENT NO. MEAT ROOM NTR	NO. FRUIT & VEG NTR	NO. BUTTER EGG NTR	NO. VESTIBULE NTR	NO. FREEZE ROOM NTR	NO. CHILL ROOM NTR	NO. NTR	NO. NTR	REMARKS
					15 / 18	40 / 43	32 / 35	45 / 48	0 / 3	33 / 36			
0200					15	42	32	44	2	34			
0400					14	40	32	46	1	33			0400 added 1 pint of oil to No. 2 Compressor.
0600													
0800													
1000													
1800													
2000													
2200													
2400													

GENERAL REMARKS

PLATE NO. 10506 (2)

B

47.104

Figure 11-15.—Refrigeration/Air Conditioning Equipment Operating Record, NAVSEC 95901/1. A. Front. B. Back.

System, Subsystem, or Component	**Reference Publications**
Main Refrigeration and Air-Conditioning Plants	

Bureau Card Control No.						Maintenance Requirement	M.R. No.	Rate Req'd.	Man Hours	Related Maintenance
A9	ZZ5FCMO	84	6056	W		1. Vent air from condenser waterheads.	W-1	MM3	0.5	None
AC	ZZZFCW4	65	A557	W		1. Lubricate flexible couplings.	W-2	MM3	0.2	None
A9	ZZ6FST2	84	6057	M		1. Clean sea water strainers.	M-1	FN	1.5	None
AC	ZZZFCM4	75	5030	Q		1. Clean air cooled condensers.	Q-1	FN	0.3	None
AC	ZZZFACO	65	A546	Q		1. Measure compressor thrust clearance. 2. Inspect flexible coupling between compressor and speed increaser. 3. Inspect flexible coupling between motor and speed increaser.	Q-2	MM1 FN	2.0 2.0	None
A9	ZZ9FRMO	26	4948	Q		1. Inspect drive belt tension.	Q-3	MM3	0.1	None
A9	ZZ9FRMO	65	A547	Q		1. Inspect setting of safety devices. 2. Inspect door gaskets for material condition and cooling coils for amount of frost.	Q-4	MM2 FN	0.5 0.5	None
AC	ZZZFCUA	75	7044	Q		1. Clean oil cooler tubes.	Q-5	MM3 FN	1.5 1.5	None
AC	ZZZFACO	65	A548	Q		1. Inspect setting of safety devices.	Q-6	MM2 FN	1.5 1.5	None
A9	ZZ5FCMO	85	5959	S		1. Clean cooling water condenser tubes.	S-1	MM3 FN	3.0 3.0	None
A9	ZZPFCW4	74	4697	S		1. Inspect flexible coupling on compressor.	S-2	MM2	0.3	None
AC	ZZZFACO	65	A549	S		1. Clean lube oil strainer on speed increaser. 2. Renew oil in speed increaser sump. 3. Renew lube oil filter element in seal oil reservoir. 4. Clean breather on speed increaser.	S-3	MM3 FN	1.2 1.2	None
AD	ZZZFRMO	C5	6669	A		1. Sound and tighten foundation bolts.	A-1	MM3	0.1	None

MAINTENANCE INDEX PAGE
OPNAV FORM 4700-3 (4-64)

BUREAU PAGE CONTROL NUMBER A-6/72-65

98.171

Figure 11-16.—Maintenance schedule for refrigeration and air conditioning plants.

joins the suction line, between the freeze room and the suction valve; therefore, hot gas admitted to the freeze room cooling coil flows "backwards" through the coil—that is, the hot gas flows in a direction opposite to the flow of refrigerant under normal operating conditions.

When it is desired to defrost the coils of the freeze room, the normal refrigerant-liquid supply and suction return-line valves of the freeze room cooling coil are closed. The valve in the hot-gas supply line is then opened; compressed refrigerant-gas is admitted to the coil. As the frost melts on the exterior coil surfaces, the gas is condensed in the coils and becomes a liquid. The liquid is led, from the inlet end of the freeze room cooling coil, to the main liquid supply line and is utilized in the other compartments.

Upon completion of the defrosting process, the system is returned to its normal operating condition by closing the defrosting valves and opening the valves in the refrigerant-liquid supply line to the freeze room coil, and the suction return valve from the freeze room coil. Care must be taken that all liquid refrigerant has been discharged from the freeze room coil before the suction line valve from the compartment is opened. Proceed as previously outlined in step 5 for starting the compressor using the tail coil suction valve, vice the compressor suction valve, as the control valve. If all the liquid has not been discharged, liquid slugs may be returned to the compressor.

Pumping Down A Refrigerant System

The pumping-down procedure to be followed will depend on the maintenance to be done. In some cases, the necessary maintenance can be performed on the charged system after a part to be repaired or replaced has been isolated. Generally, it is possible to pump down any part of a charged system except the condenser, the liquid receiver, and the compressor discharge line. When repairs are to be made to a major portion of the system, the refrigerant system must be pumped down to return all refrigerant to the receiver. If repairs are to be made to the receiver, the condenser, or the compressor discharge line, the entire system must be drained into spare refrigerant drums. However, in systems having valves to isolate the compressor discharge line and condenser, and where it is not objectionable to release refrigerant (which may still be trapped in the condenser after the system has been pumped down to the receiver) to the atmosphere, repairs to the compressor discharge line and condenser may be made with this section isolated.

Whenever it is necessary to open a charged system in order to make repairs or replacements or to clean strainers, the refrigerant pressure within the part of the system to be opened should be pumped down to a pressure slightly above atmospheric (1/2 to 2 psig) before any connections are broken. It is generally possible to pump down any part of the system (except the condenser, the liquid receiver, and the compressor discharge line) by proper manipulation of cutout valves. As a part of the system which contains liquid R-12 is pumped down, its temperature will decrease as a result of the evaporation of the liquid refrigerant. When the temperature of such a part of the system begins to rise to normal again, while the low pressure in the part is maintained, it is reasonably certain that all R-12 liquid within the part has been evaporated.

If, in the final evacuation of a part of the system, a pressure of less than 0 psig is reached, sufficient refrigerant should be immediately bled into the evacuated part of the system to raise the pressure to between 1/2 and 2 psig. Connections may then be opened; and repairs, replacements of parts, or other necessary service operations may be accomplished.

When a refrigerant system is opened, the free ends of the refrigerant lines should be temporarily plugged in order to prevent the entrance of air and dirt. When the connections are remade, one connection is made tight while the other connection is left loose, temporarily, so that the air or other foreign gases in the section of the system which is serviced can be swept out through the free end as this section of the system is slowly purged with refrigerant-gas bled from the charge in the system. The other connection (or connections) is then quickly tightened. Refrigerant, oil-charging, gage, and control lines, although generally of small size and short length, should be purged with refrigerant-gas immediately before they are connected to the system. Where connecting lines which have been removed are to be used again, the ends of the lines should be capped to protect the connecting fitting and to ensure that the tube will be clean when it is used again.

When MAJOR REPAIRS are to be made to a major portion of the system or when the system is to be secured for an extended period, the

refrigerant system must be pumped down to return all refrigerant to the receiver. Sufficient refrigerant-gas should be retained within the system to create a positive pressure of approximately 2 psig throughout the circuit, except within the compressor-discharge line and the condenser, and between the receiver and the main liquid-line shutoff valve. To pump down the system, close the main liquid-line shutoff valve and the dehydrator-bypass valve (if installed), and open the cooling-coil solenoid valves. Allow the compressor to operate on manual control until the suction pressure reaches approximately 1/2 to 2 psig; then stop the compressor. Repeat the operation until the liquid refrigerant in the circuit has evaporated and the suction pressure remains relatively constant at 1/2 to 2 psig. During the pump-down period, the evaporation of liquid refrigerant can be traced to the liquid line back to the main liquid-line shutoff valve by the formation of frost and its subsequent melting as the liquid refrigerant is evaporated and superheated. Open the power-supply switch to the compressor; close the compressor suction and discharge shutoff valves. Shut off the water supply to the condenser and drain the condenser water. Where the amount of liquid refrigerant contained in the system is in excess of the capacity of the receiver, the surplus liquid refrigerant must be drawn off into separate refrigerant drums.

To drain the refrigerant charge from the system when it is necessary to make repairs to the condenser, the liquid receiver, or the compressor discharge line, or for any other reason, proceed as follows:

1. Start the compressor and pump down the cooling coil and suction-line pressure, with the liquid-line valve at the receiver outlet closed, to the point at which the low pressure control switch stops the unit.
2. When the compressor is stopped by the low pressure cutout switch, restart the unit manually and continue the pumping-down procedure until the suction pressure reaches approximately 2 psig and stop the compressor. Repeat the operation in periodic cycles until the liquid refrigerant in the circuit has evaporated and the suction pressure remains relatively constant between 1/2 and 5 psig.
3. Close the compressor discharge line valve; close all liquid valves at the cooling coils.
4. Connect an empty R-12 service drum to the refrigerant drain valve. (Before connecting the drum to the R-12 system, cool the drum thoroughly and thus permit rapid draining of the refrigerant into the drum.) Always use a clean R-12 service drum containing no air or water so that the drained R-12 may be kept in suitable condition for future use.
5. Purge the air out of the line connecting the drain valve and the drum by leaving the connection at the drum valve open as you slowly flush refrigerant through the line and out at the connection; then close the connection. The R-12 may now be drained into the cooled drum by opening the drain valve and the service drum valve.
6. When the service drum is full, close the drain valve and permit the R-12 liquid in the drain line to evaporate; then close the service drum valve and disconnect the drum from the system.
7. Weigh the drum while filling, to be certain that it is not overcharged. The net and gross weights are stamped on the drum. (These weights include that of the cast iron protector cap which fits over the cylinder valve.)

> CAUTION: Never fill a service drum beyond its rated capacity; drum rupture may result from hydraulic pressure upon rise in temperature.

8. Discharge the R-12 vapor, which remains in the condenser and receiver to the atmosphere through the purge valve.

Testing for Refrigerant Leaks

Refrigerant leaks mean the loss of the refrigerating effect and loss of refrigerant. Various tests are used to determine the existence of leaks in refrigerant systems. Pressure tests are used after the installation of a system and after extensive repairs or replacement of parts have been made. Pressure tests are made before the system is charged with refrigerant. Charged systems are tested for leakage either with a halide leak detector, electronic refrigerant gas detector, or with soapsuds; which of the three methods to be used will depend largely upon the size of the leak, and upon the type of space in which the test is to be performed.

As an MM, you will be required to know how to use the detectors and how to use soapsuds to check for the refrigerant leakage.

In addition to those tests for leaks which are made at periodic intervals, tests should be

made before the compressors are started and at any other time that a shortage of refrigerant in the system is suspected. Unusual operating conditions which indicate a shortage of refrigerant in the system are:

1. High suction-line temperatures.
2. Relatively high crankcase and cylinder temperatures.
3. Excessively high refrigerant temperature in the liquid line.
4. Bubbles in the refrigerant sight-flow indicator.
5. Liquid refrigerant carrying partially through the coil, with considerable superheat at the thermal element.
6. Short cycle or compressor running continuously.
7. Excessive oil seepage at shaft seal connection.
8. Oil seepage at refrigerant-system piping and compressor connections.

A shortage of refrigerant in the system nearly always indicates the presence of leaks. When a shortage of refrigerant is found the entire system should be tested for leaks by one of the following methods.

The use of a HALIDE LEAK DETECTOR is the most positive method of detecting leaks in a refrigerant system. Such a detector consists essentially of a torch burner, a copper reactor plate, and an exploring hose. (See fig. 11-17.)

Most detectors use either acetylene gas or alcohol as a fuel. Pressure for detectors which use alcohol is supplied by a pump. If a pump-pressure type of alcohol-burning detector is used, be sure that the air pumped into the fuel tank is pure.

Atmosphere suspected of containing R-12 vapor is drawn, by injector action, through the exploring hose into the torch burner of the detector. Here the air passes over the copper reactor plate, which is heated to incandescence. If there is a minute trace of R-12 present, the color of the torch flame will change from a blue (neutral) to green as the R-12 comes in contact with the reactor plate. The shade of green will depend upon the relative amount of R-12 present; a pale green indicates small concentrations and a darker green shows heavier concentrations. Excessive quantities of R-12 will cause the flame to burn with a vivid purple color. Extreme concentrations of R-12 may extinguish the flame by crowding out the oxygen available from the air.

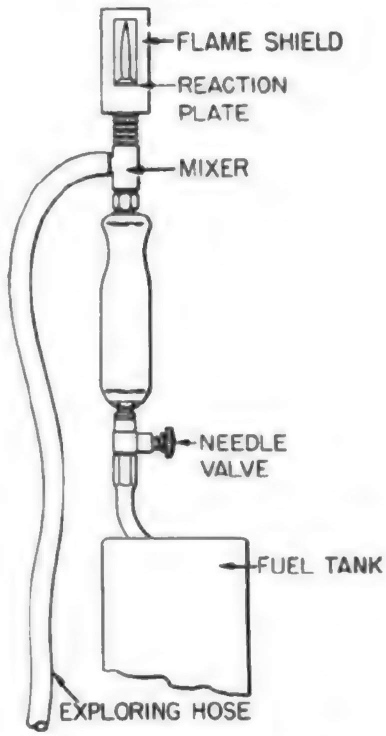


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Figure 11-17.—Halide leak detector.

When a leak detector is used, best results are obtained if the following precautions are observed:

1. Be sure that the reactor plate is properly in place.
2. Adjust the flame so that it does not extend beyond the end of the burner. (A small flame is much more sensitive than a large flame. If difficulty is experienced in lighting the torch when it is adjusted to produce the necessary small flame, block the end of the exploring hose until the fuel ignites; this will reduce the amount of oxygen drawn in. Then gradually open the hose.)
3. Clean out the exploring tube if the flame continues to have a white or yellow color. (A white or yellow flame indicates that the exploring tube is partially blocked with dirt.)
4. Check to see that air is being drawn into the exploring tube; this check can be made, from time to time, by holding the end of the tube to your ear.

5. Hold the end of the exploring tube close to the joint being tested; this prevents dilution of the sample by stray air currents.

6. Move the end of the exploring hose tube slowly and completely around each joint being tested. (Leak testing cannot be safely hurried. There is a definite time lag between the moment when air enters the exploring tube and the moment it reaches the reactor plate; permit sufficient time for the sample to reach the reactor plate.)

7. If a greenish flame is noted at any time, repeat the test in the same vicinity until the source of the refrigerant is determined.

A halide torch or an electronic refrigerant gas detector is so sensitive that it is useless if the atmosphere is contaminated by excessive leakage of R-12. This is most likely to happen in a small or poorly ventilated compartment. If a compartment is contaminated by R-12 and cannot be ventilated, the SOAPSUDS TEST must be used.

In using the soapsuds test, prepare the soap-and-water solution so that it has the consistency of liquid hand soap, and will work up a lather on a brush. (The lather will remain wet for a longer period if a few drops of glycerin are added to the solution.)

Apply the lather all the way around the joint; then look carefully for bubbles. If a joint is so located that a part of it is not visible, use a small mirror when inspecting that part.

Remember that it sometimes takes a minute or more for bubbles to appear, if the leak is small. Doubtful spots should be lathered and examined a second time.

Always follow a definite procedure in testing for refrigerant leaks, so that no joints will be missed. The extra time spent in testing all joints will be justified. Even the smallest leak is not to be considered negligible. However insignificant the leak may seem, it eventually empties the system of its charge to the point of faulty plant operation. Because R-12 is practically odorless, the first indication that leakage exists is the loss of refrigerating effect. A refrigerant system should never be recharged until all leaks are discovered and definitely repaired.

Never use oil to test for R-12 leaks. Oil is not reliable because of the capacity of the oil for absorbing R-12. If a small leak should exist where oil has been applied, the R-12, will be absorbed by the oil and will show no indication (bubbles) of the leak until the oil is saturated with R-12. Furthermore, if a halide torch is used to test a joint that has been tested previously with oil, the torch will give a false indication because of the R-12 released from the oil.

Testing For Air and Noncondensable Gases

It is essential that every resonable precaution be taken to keep air and noncondensable gases out of a refrigerant system. When air enters the system the condenser must be purged, with a resultant loss of refrigerant. Atmospheric air always contains some moisture, which will enter the system when air does. A refrigerant system must be kept as moisture-free as possible to eliminate such troubles as the freezing of water at the expansion valves, internal oxidation or corrosion of parts, and emulsification or sludging of lubricating oils.

Air and noncondensable gases in a refrigerant system are pumped through the system and are discharged by the compressor into the condenser. These gases are trapped in the condenser by the liquid seal maintained over the receiver outlet. These gases are, in general, lighter than the relatively dense R-12 vapor; they tend to collect, therefore, in the upper part of the condenser when the compressor is stopped. The purge valve for discharging these gases to the atmosphere is located either in the upper part of the condenser shell or in the compressor discharge line above the condenser. While the compressor is in operation, any noncondensable gases in the system are thoroughly mixed with the R-12 vapor. This mixing is caused by the turbulence produced by the rapidly pulsating discharge of refrigerant into the condenser. Therefore, it is not advisable to attempt to purge noncondensable gases from the system while the compressor is in operation. Noncondensable gases in a condenser cause excessive condensing pressures with a resultant loss in plant efficiency.

The best time to check an R-12 system for noncondensable gases is immediately before the compressor starts after a shutdown period. When a condenser is to be checked for noncondensable gases, it is essential that the gages and thermometers used be accurate and that the system have sufficient refrigerant charge so that the liquid refrigerant present in the receiver will seal the liquid-line connection.

The following procedure should be followed when checking a refrigerant system for noncondensable gases:

1. Close the liquid-line valve.
2. Shut off the compressor and close the suction-line valves.
3. Determine the actual condensing temperature of the refrigerant.

A service gage should be installed in the compressor discharge connection if a discharge-pressure gage is not already provided. An approximation of the actual condensing temperature of the refrigerant will be reached when no further decrease is noted in the discharge pressure. (On water-cooled condensers, the reduction in pressure can be accelerated by permitting circulation of condenser water until discharge pressure is reduced.) The thermometer provided on most ships in the liquid line at the receiver will indicate the actual condensing temperature. If a thermometer is not installed in an air-cooled condenser application, one should be placed near the condenser to record the ambient temperature at that location. When the temperature of an air-cooled condenser has dropped to the ambient temperature, the reading of the thermometer will approximate the actual condensing temperature.

4. On the compound pressure gage, read the condensing temperature which corresponds to the condensing pressure registered by the high pressure gage; the temperature indicated on the temperature scale is the condensing temperature of pure R-12 at the pressure indicated by the gage.
5. Subtract the existing condensing temperature from the condensing temperature of pure R-12 at the existing condenser pressure. If the difference between these two temperatures is more than 5° F, it will be necessary to purge the condenser of noncondensable gases.

If the above test indicates the need for PURGING, slowly release the noncondensable gases. When a purge valve is not provided, purge the gases by opening the discharge pressure gage connection.

The proportion of R-12 gas that will mix with the condensable gases and escape while the condenser is being purged will depend upon the rate of purging and upon the concentration of the noncondensable gases in the condenser. No practical test is available aboard ship to determine definitely when an excessively high proportion of R-12 gas is being purged with the noncondensable gases. To keep the R-12 loss to a minimum when the condenser is being purged, purge slowly; and frequently check the condenser for noncondensable gases. R-12 is odorless in concentrations of less than 20 percent by volume in air; in heavier concentrations, however, it resembles carbon tetrachloride in odor. If you can get close to the purge-valve discharge, you may be able to determine by the odor of the purged gases when purging should be discontinued and when the check for noncondensable gases should be repeated. Protect your eyes with goggles when you are checking the odor of purged gases.

Checking Compressor Oil

If the apparent oil level observed immediately after a prolonged shutdown period is lower than normal, it is almost certain that the actual working oil level is far too low. After a sufficient quantity of oil has been added to raise the apparent oil level to the center of the bull's-eye sight-glass, the actual oil level should be checked as follows:

1. Operate the compressor on MANUAL control for at least one hour. If the compressor is operating on a water cooler or other coil which is apt to freeze, observe the temperature and interrupt compressor operation as necessary to prevent freezing. Repeat cycling until the total running time (one hour) is obtained. Then slowly close the suction line stop valve.
2. Stop the compressor. If the compressor is force lubricated, immediately observe the oil level in the sight-glass. If the compressor is splash lubricated, turn the flywheel until the crankshaft and connecting rod ends are immersed in the lubricating oil, then check the oil level.

To check the oil level when the compressor has been running on its normal cycle, with no abnormal shutdown period, proceed as follows:

1. Wait until the end of a period of operation; if the operation is continuous, wait until the compressor has been in operation at least 1/2 hour, then stop the compressor.
2. As soon as the compressor stops, observe the oil level in the sight-glass on force-lubricated compressors. If the compressor is splash lubricated, turn the flywheel until the crankshaft and connecting rod ends are satisfactorily immersed in the lubricating oil; then check the oil level.

Do not remove oil from the crankcase because of an apparent high level unless too much oil has been previously added, or unless it is apparent that oil from the crankcase of one compressor of the plant has been inadvertently deposited in the crankcase of another.

However, if the oil level is lower than its recommended height on the glass, a sufficient quantity of oil should be added to obtain the desired level. Do not add more oil than is necessary; too much oil can result in excessive oil transfer to the cooling coils.

ADDING OIL.—There are two common methods of adding oil to a compressor. In one type of installation, a small oil-charging pump is furnished for adding oil to the compressor crankcase. In another type, oil is placed in the compressor by means of a clean, well-dried funnel. In either installation, care must be taken to prevent the entrance of air or foreign matter into the compressor.

When performing hourly checks of the compressors, you may observe no oil in the crankcase, or a very low oil level on the sight-glass. This indicates that the oil has left the compressor and is circulating in the system; and it will be necessary to add oil and operate the system. After the compressor has reclaimed the excessive oil in the system, the excess oil should be drained.

REMOVING OIL.—To remove oil from the compressor crankcase, reduce the pressure in the crankcase to approximately 1 psi by gradually closing the suction line stop valve. Then stop the compressor, and close the suction and discharge line valves, loosen the lubricating oil drain plug near the bottom of the compressor crankcase, and allow the required amount of oil to drain out. Since the compressor crankcase is under a slight pressure, do not fully remove the drain plug from the compressor, but allow the oil to seep out around the threads of the loosened plug. When the desired amount of oil has been removed, tighten the drain plug, open the suction and discharge line valves, and start the compressor. If an oil drain valve is provided in lieu of a plug, the required amount of oil may be drained without pumping down the compressor.

RENEWING THE LUBRICATING OIL.—When clean copper tubing is used for R-12 systems, and reasonable care has been taken to prevent the entrance of foreign matter and moisture during installation, the oil in the compressor crankcase will probably not become so contaminated that it requires renewal more than once a year. When iron or steel pipe and fittings are used in the R-12 system, a sample of oil from the compressor crankcase should be withdrawn into a clean glass container every 3 months. If the sample shows contamination, all the lubricating oil should be renewed. It is good practice to check the cleanliness of the lubricating oil after each cleaning of the compressor suction scale trap.

Care of V-Belts

Excessive looseness will cause slippage, rapid wear, and deterioration of V-belts. On the other hand, a belt that is too tight will cause excessive wear of both the belt and the main bearing of the compressor. In extreme cases it may cause a bad seal leak. When properly tightened, a belt can be depressed 1/2 to 3/4 inch, by the pressure of one finger, at a point midway between the flywheel and the motor pulleys.

When replacement of one belt of a multiple V-belt drive is necessary, a complete new set of matched belts should be installed. Belts stretch considerably during the first few hours of operation. Replacement of a single belt will upset the load balance between the new and old belts and will be a potential source of trouble. It is better practice to run the unit temporarily with a defective belt removed than to attempt to operate a new belt in conjunction with two or more seasoned belts.

V-belts, motor pulleys, and compressor flywheels should be kept dry and free of oil. Belt dressing should never be used.

Setting Control and Safety Devices

A refrigeration plant cannot operate EFFICIENTLY and SAFELY unless the control and safety devices are in good working order and set properly. When a new control or safety device is installed in a refrigeration system, it must be adjusted or set to function at pressures or temperatures in accordance with the plant design. Periodic tests and inspections may indicate faulty plant operation that is due to improperly adjusted control or safety devices. As a Machinist's Mate, you must know how these devices operate and how to adjust them.

This section contains information on some of the more common types of control and safety devices used by the Navy.

The methods of setting the low pressure switch, the water failure switch, and the thermostatic switch are similar; however, these switches differ as to operating range, purpose, and setting. Also, the high pressure switch and the water failure switch are safety devices while the low pressure switch and the thermostatic switches are control devices.

For detailed information, consult Naval Ships Technical Manual and the manufacturer's technical manuals.

The HIGH PRESSURE SWITCH has an operating range of 60 to 350 psig and an adjustable differential (difference between the cut-in point and cutout point). As mentioned earlier in the chapter, the switch should be set to cut out at 160 psig and to cut in at 140 psig. To set the switch, first remove the cover plate. Then the two adjusting screws; one labeled differential, the other labeled range, are easily accessible. Turning the range adjusting screw to the right raises both the cut-in point and cutout point. Turning it to the left lowers these points. The differential adjustment affects only the cutout point. Turning it to the right raises the cutout point and turning it to the left lowers the cutout point. Start the compressor and control the discharge pressure by throttling the circulating water through the condenser. Turn the differential screw all the way to the left and turn the range screw all the way to the right. Raise the compressor discharge to 150 psig. Turn the range screw to the left until the contactor in the switch opens, thereby stopping the compressor. When the discharge pressure drops to 140 psig, turn the range screw to the right until the contacts close, starting the compressor. The cut-in point is now set. With the compressor running, turn the differential screw all the way to the right, then raise the discharge pressure to 160 psig. Turn the differential screw to the left until the contacts open, stopping the compressor. The cutout point is now set.

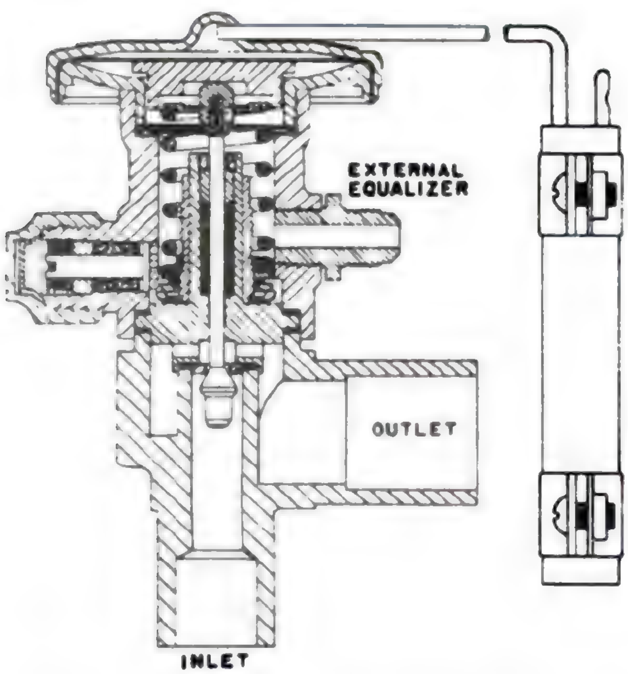
The LOW PRESSURE SWITCH has an operating range of 20 inches of vacuum to 80 psig and an operating differential of 9 psig to 30 psig.

To set the low pressure switch, start the compressor and control the suction pressure by throttling the compressor suction valve. Turn the range and differential adjustment screws to the left. Lower the suction pressure to about 10 psig below the desired cut-in pressure and turn the range screw to the right until the switch contacts open, stopping the compressor. Allow the suction pressure to rise to the desired cut-in pressure and turn the range screw to the left until the switch contacts close, starting the compressor. The cut-in point is now set. Turn the differential screw all the way to the right, throttle the suction valve to lower the suction pressure to the desired cutout pressure. Turn the differential screw to the left until the switch contacts open, stopping the compressor. The cutout point is now set.

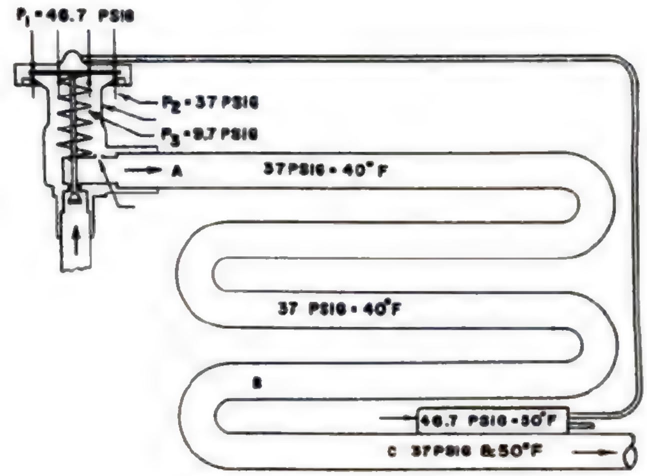
The WATER FAILURE SWITCH should be set to cut in at 15 psig and to cut out at 5 psig. To set the water failure switch, turn the differential screw to the left limit for minimum differential since the required differential (difference between cut-in and cutout points) is 10 psig. Throttle water overboard valve until a pressure of 15 psig is maintained at the condenser inlet. Turn the range screw clockwise until the switch contacts open, then turn counterclockwise slowly until contacts close. Slowly shut off water supply, decreasing the pressure. The contacts should open at 5 psig.

The THERMAL EXPANSION VALVE is generally factory set and seldom needs adjustment. The design and construction of expansion valves vary greatly. Figure 11-18 shows a cross sectional assembly view of a type which is generally used aboard ship. Other designs may have different arrangements for adjustment, sealing, and control.

Figure 11-19 shows a sketch of a thermal expansion valve and a cooling coil operating under assumed conditions of 40° evaporating temperatures with a valve adjusted to operate with a 10° superheat and with negligible pressure loss in the cooling coil. The 40° has a corresponding pressure of approximately 37 psig. As long as any liquid exists in the coil at this pressure the refrigerant temperature will remain at 40°. As the liquid approaches point B on the cooling coil, it becomes evaporated due to the rate of liquid feed by the valve and due to the absorption of heat equal to the latent heat of vaporization of the refrigerant from the surrounding atmosphere. The refrigerant as a gas continues along the coil at a pressure of 37 pounds until at point C its temperature has increased to 50° due to the continued absorption



87.64
Figure 11-18.—Single outlet thermal expansion valve.



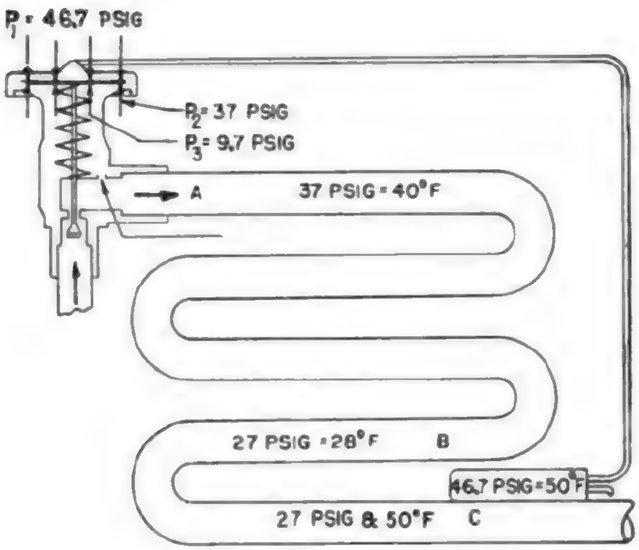
87.65
Figure 11-19.—Thermal expansion valve with internal equalizer on evaporator with no pressure drop.

of heat from outside the coil. This then represents the 10° superheat (50°-40°). The amount of the superheat is dependent upon the amount of refrigerant fed by the expansion valve and the load to which the cooling coil is exposed.

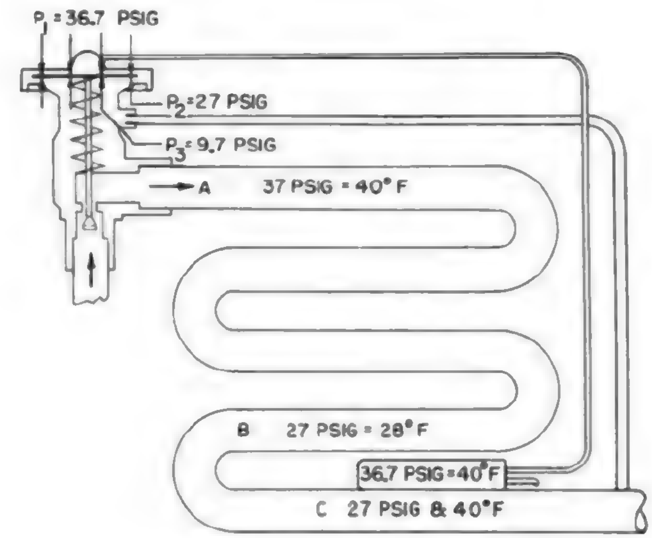
Since the cooling coil temperature at C is 50°, the thermal bulb strapped to the coil at this point also will be 50°. The temperature of the thermal bulb affects the pressure of the refrigerant within the bulb so that it has an internal pressure equal to 46.7 psig. This pressure, shown as P_1, is the pressure exerted on top of the diaphragm. The pressure, P_2, exerted on the underside of the diaphragm is a result of the pressure of 37 psig at point A (expansion valve has an internal equalizer). The pressure, P_3, is that exerted by the spring under compression.

The movement of the diaphragm in response to pressure operates the valve stem to modulate the valve opening and to control flow. When the cooling load decreases, the rate of refrigerant feed would extend beyond point B resulting in a temperature lower than 50° at point C with a smaller superheat condition. The thermal bulb, in turn, would have lower temperature with a correspondingly lower pressure so that the reduced pressure exerted on top of the diaphragm would cause the valve to start to close until a balancing point was reached reducing the flow of refrigerant. On the other hand if the cooling load is increased, liquid refrigerant would be vaporized before it reached point B, resulting in more superheat by the time the gas passed point C. This in turn would raise the temperature of the thermal element increasing the pressure on top of the diaphragm causing the valve to open to admit more refrigerant. It will be noted in the example that the valve attempted to maintain a predetermined superheat represented by the spring pressure, P_3. The pressure is adjustable to increase or decrease the superheat setting and is usually maintained from 5° to 10° depending on the application.

An external equalizing connection, shown in figure 11-18 is required where the refrigerant pressure loss through the cooling coil is of any consequence: such as, above 2 1/2 pounds for air conditioning, 1 1/2 pounds for middle range refrigeration and 1/2 pound for frozen food applications. The need for an external equalizing port can be described by using figure 11-20. Assume the pressure loss through the coil is 10 pounds. This would result in a pressure at point B of 37 psig minus 10 psig or 27 psig



87.66
Figure 11-20.—Thermal expansion valve with internal equalizer on evaporator with 10 psi drop.



87.67
Figure 11-21.—Thermal expansion valve with external equalizer on evaporator with 10 psi pressure drop.

which is equivalent to an evaporating temperature of approximately 28°. Pressure at point A would still be 37 psig and the pressure at the underside of the diaphragm would still be 37 psig plus 9.7 psig or 46.7 psig. The required pressure above the diaphragm for equalization purposes would be 46.7 psig equivalent to a thermal bulb temperature of 50°. However, the difference between the superheated temperature at 50° at point C and 28° evaporating temperature at point B results in a 22° superheat. This increase in superheat from 10° to 22° makes it necessary to use more of the cooling coil surface for superheating the vapor rather than for absorption of latent heat by the liquid and so the cooling coil is not fully utilized. The thermal expansion valve provided with an external equalizer must be used where such a condition exists. Figure 11-21 shows the connection with external equalizer, resulting in using the pressure of 27 psig at C and applying it directly to the underside of the diaphragm P_2 for a true response to superheat temperature.

Thermal expansion valves are rated by the manufacturer in tons of refrigeration for various refrigerant evaporating temperatures and pressure differentials across the valve. These ratings are based generally on an assumed 1° sub-cooling of the liquid refrigerant at the entrance to the valve. This requires that each valve be selected not only for the tonnage needed for the cooling coil it serves but also for the conditions of pressure and temperature of the refrigerant at the inlet and downstream of the valve for its specific location in the refrigerating piping system. Thus, it becomes necessary to determine pressure losses including vertical rise of liquid and anticipate realistic operating conditions in order to properly select a valve of adequate size.

When the thermostatic expansion valve is operating properly, the temperature at the outlet side of the valve is much lower than that at the inlet side. If this temperature difference does not exist when the system is in operation, the valve seat is probably dirty and clogged with foreign matter.

Once a valve is properly adjusted, further adjustment should not be necessary. The major trouble encountered can usually be traced to moisture or dirt collecting at the valve seat and orifice. The symptoms of improper valve operation should be carefully analyzed before concluding that the valve is out of adjustment. Once a valve is properly adjusted, additional adjustment should not be necessary unless changes are made to the cooling coil arrangement or thermal element location.

By means of a gear and screw arrangement, the thermostatic expansion valve is adjusted

to maintain a superheat ranging approximately from 4°F to 12°F at the cooling coil outlet. The proper superheat adjustment varies with the design and service operating conditions of the valve, and the design of the particular plant. Increased spring pressure increases the degree of superheat at the coil outlet and decreased pressure has the opposite effect. Many thermostatic expansion valves are initially adjusted by the manufacturer to maintain a predetermined degree of superheat, and no provision is made for further adjustments in service.

If expansion valves are adjusted to give a high degree of superheat at the coil outlet, or if the valve is stuck shut, the amount of refrigerant admitted to the cooling coil will be reduced. With an insufficient amount of refrigerant, the coil will be "starved" and will operate at a reduced capacity. Compressor lubricating oil carried with the refrigerant may tend to collect at the bottom of the cooling coils, thus robbing the compressor crankcase, and providing a condition whereby slugs of lubricating oil may be drawn back to the compressor. If the expansion valve is adjusted for too low a degree of superheat, or if the valve is stuck open, liquid refrigerant may flood from the cooling coils back to the compressor. Should the liquid collect at a low point in the suction line or coil, and be drawn back to the compressor intermittently in slugs, there is danger of injury to the moving parts of the compressor.

In general, the expansion valves for air conditioning and water cooling plants (high temperature installations) must be adjusted for higher superheat than are the expansion valves for cold storage refrigeration and ship's service store equipment (low temperature installations).

If it is impossible to adjust expansion valves to the desired settings, or if it is suspected that the expansion valve assembly is defective and requires replacement, appropriate tests must be made. (First be sure that the liquid strainers are clean, that the solenoid valves are operative, and that the system is sufficiently charged with refrigerant.)

The major equipment required for expansion valve tests is as follows:

1. A service drum of R-12, or a supply of clean dry air at 70 to 100 psig. The service drum is used to supply gas under pressure. The gas used does not have to be the same as that employed in the thermal element of the valve being tested.

2. A high pressure and a low pressure gage. The low pressure gage should be accurate and in good condition so that the pointer does not have any appreciable lost motion. The high pressure gage, while not absolutely necessary, will be useful in showing the pressure on the inlet side of the valve. Refrigeration plants are provided with suitable spare and test pressure gages.

The procedure for testing is as follows:

1. Connect the valve inlet to the gas supply with the high pressure gage attached so as to indicate the gas pressure to the valve, and with the low pressure gage loosely connected to the expansion valve outlet. The low pressure gage is connected up loosely so as to provide a small amount of leakage through the connection.

2. Insert the expansion valve thermal element in a bath of crushed ice. Do not attempt to perform this test with a container full of water in which a small amount of crushed ice is floating.

3. Open the valve on the service drum or in the air supply line. Make certain that the gas supply is sufficient to build up the pressure to at least 70 psi on the high pressure gage connected in the line to the valve inlet.

4. The expansion valve can now be adjusted. If it is desired to adjust for 10°F superheat, the pressure on the outlet gage should be 22.5 psig. This is equivalent to an R-12 evaporating temperature of 22°F, and since the ice maintains the bulb at 32°F, the valve adjustment is for 10° superheat (difference between 32 and 22). For a 5° superheat adjustment, the valve should be adjusted to give a pressure of approximately 26.1 psig. There must be a small amount of leakage through the low pressure gage connection while this adjustment is being made.

5. To determine if the valve operates smoothly, tap the valve body lightly with a small weight. The low pressure gage needle should not jump more than 1 psi.

6. Now tighten the low pressure gage connection so as to stop the leakage at the joint, and determine if the expansion valve seats tightly. With the valve in good condition, the pressure will increase a few pounds and then either stop or build up very slowly. With a leaking valve, the pressure will build up rapidly until it equals the inlet pressure.

7. Again loosen the gage so as to permit leakage at the gage connection; remove the thermal element, or control bulb, from the

crushed ice, and warm it with the hand or place it in water that is at room temperature. When this is done, the pressure should increase rapidly, showing that the power element has not lost its charge. If there is no increase in pressure, the power element is dead.

8. With high pressure showing on both gages as outlined above, the valve can be tested to determine if the body joints or the bellows leak. This can be done by using a halide leak detector. When performing this test, it is important that the body of the valve have a fairly high pressure applied to it. In addition, the gages and other fittings should be made up tightly at the joints so as to eliminate leakage at these points.

If it is evident that the expansion valve is defective, it must be replaced. Often it is possible to replace a faulty power element or other part of the valve without having to replace the entire assembly. When replacement of an expansion valve is necessary, it is important to replace the unit with a valve of the same capacity and type, designed for R-12 systems.

The WATER REGULATING VALVE should be adjusted to maintain a compressor discharge pressure of approximately 125 psig. To raise the valve opening point, turn the adjusting nuts clockwise, increasing tension on the main springs. Increasing main spring tension increases the amount of pressure required to open the valve. Turning the adjusting nuts counterclockwise decreases the main spring tension, therefore decreasing the amount of pressure required to open the valve. If the ambient temperature is high, pressure (gas) in the compressor discharge line and condenser may remain high and cause the water regulating valve to partly open when the compressor is idle. In such instances, the point of valve opening should be raised just enough to cause the valve to close during compressor shutdown.

The valve may be flushed by opening it with an outside force, a screwdriver or similar tool may be used to force the spring yoke.

The THERMOSTATIC SWITCH which operates the solenoid valve is similar to the low pressure switch. Tubing connects a bellows in the thermostatic switch to a thermal bulb in the compartment being cooled. The thermal bulb and tubing are charged with R-12 or some other volatile liquid. Temperature changes in the refrigerated compartment cause corresponding pressure changes of the actuating medium in the thermal bulb. These pressure changes are transmitted to the thermostatic switch, through the connecting tubing. To set or adjust the cut-in and cutout points of the thermostatic switch, the same procedure is used as in setting and adjusting the low pressure switch.

When condenser circulating water is obtained from the firemain, the pressure must be reduced. For this pressure reduction, an AUTOMATIC REDUCING VALVE is installed in the branch line leading from the firemain to the condenser. The reducing valve is installed just ahead of the regulating valve. While maintenance of the reducing valve is usually a responsibility of the Hull Maintenance Technician, the Machinist's Mate may have to adjust the reducing valve to raise or lower the outlet pressure. The outlet pressure can be varied by turning the adjusting screw, which is located under the cap. Turning the adjusting screw clockwise increases the pressure applied by the spring to the top of the diaphragm, thus opening the valve wider and increasing the outlet pressure. Turning the adjusting screw counterclockwise decreases the spring pressure on the top of the diaphragm, thus tending to decrease the discharge pressure.

CHARACTERISTICS OF REFRIGERANTS

Pure R-12 (CCl_2F_2) is colorless. In concentrations of less than 20 percent by volume in air, R-12 is odorless; in higher concentrations, its odor resembles that of carbon tetrachloride. It has a boiling point of -21°F at atmospheric pressure. At ordinary temperatures R-12 is a liquid when under a pressure of about 70 to 75 psig.

Mixtures of R-12 vapor and air, in all proportions, are nonirritating to the eyes, nose, throat, and lungs. The refrigerant will not contaminate or poison foods or other supplies with which it may come in contact. The vapor is nonpoisonous; it will not support respiration, however, and it produces mild anesthesia when it is inhaled in sufficient quantities. In view of its low boiling point at atmospheric pressure, care must be taken to prevent liquid R-12 from coming in contact with the eyes; the liquid will freeze the tissues of the eyes. Always wear goggles if you are to be exposed to R-12.

R-12 in either a liquid or vapor state is nonflammable and nonexplosive. R-12 will not

corrode the metals commonly used in refrigerating systems.

One hazard which may be introduced through the use of R-12 as a refrigerant is the very remote health hazard which may be presented should leakage of a large amount of the vapor come in direct contact with an open flame of high temperature (about 1,000° F) and be decomposed. In order to be a health hazard, the leakage of R-12 must be within a confined and poorly ventilated space and the vapor must come in direct contact with a high temperature flame. When these conditions exist, however, the products of decomposition are pungent and irritating, rendering them noticeable even when they are present only in minute quantities; ample warning is available before concentrations dangerous to health are reached.

R-12 is a stable compound capable of undergoing without decomposition, the physical changes required of it in refrigeration service. It is an excellent solvent and has the ability to loosen and remove all particles of dirt, scale, and oil with which it comes in contact within a refrigerating system.

R-22 ($CHClF_2$) and R-11 (CCl_3F) are colorless, nonexplosive, nonpoisonous refrigerants with many properties similar to those of R-12.

SAFETY PRECAUTIONS

Refrigerants are furnished in cylinders for use in shipboard refrigeration systems. The following precautions must be observed in the handling, use, and storage of these cylinders:

1. Never drop cylinders nor permit them to strike each other violently.
2. Never use a lifting magnet or a sling (rope or chain) when handling cylinders. A crane may be used if a safe cradle or platform is provided to hold the cylinders.
3. Caps provided for valve protection must be kept on cylinders except when the cylinders are being used.
4. Whenever refrigerant is discharged from a cylinder, the cylinder should be weighed immediately and the weight of the refrigerant remaining in the cylinder should be recorded.
5. Never attempt to mix gases in a cylinder.
6. NEVER put the wrong refrigerant into a refrigeration system! No refrigerant except the one for which the system was designed should ever be introduced into the system. Check the equipment nameplate or the manufacturer's technical manual to determine the proper refrigerant type and charge. Putting the wrong refrigerant into a system may cause a violent explosion.
7. When a cylinder has been emptied, close the cylinder valve immediately to prevent the entrance of air, moisture, or dirt. Also, be sure to replace the valve protection cap.
8. Never use cylinders for any purpose other than their intended purpose. DO NOT use them as rollers, supports, etc.
9. DO NOT tamper with the safety devices in the valves or cylinders.
10. Open cylinder valves slowly. Never use wrenches or other tools except those provided by the manufacturer.
11. Make sure that the threads on regulators or other connections are the same as those on the cylinder valve outlets. Never force connections that do not fit.
12. Regulators and pressure gages provided for use with a particular gas must NOT be used on cylinders containing other gases.
13. Never attempt to repair or alter cylinders or valves.
14. Never fill R-12 cylinders beyond 80 percent of capacity.
15. Store cylinders in a cool, dry place, in an upright position. If the cylinders are exposed to excessive heat, a dangerous increase in pressure will occur. If cylinders must be stored in the open, take care that they are protected against extremes of weather. NEVER allow a cylinder to be subjected to a temperature above 125° F.
16. NEVER allow R-12 to come in contact with a flame or red-hot metal! When exposed to excessively high temperatures, R-12 breaks down into PHOSGENE gas, an extremely poisonous substance.

Because R-12 is such a powerful freezing agent that even a very small amount can freeze the delicate tissues of the eye, causing permanent damage; it is essential that goggles be worn by all personnel who may be exposed to a refrigerant, particularly in its liquid form. If refrigerant does get in the eyes, the person suffering the injury should receive medical treatment immediately in order to avoid permanent damage to the eyes. In the meantime, put drops of clean olive oil, mineral oil, or other nonirritating oil in the eyes, and MAKE SURE that the person does not rub his eyes. CAUTION:

DO NOT use anything except clean, nonirritating oil for this type of eye injury.

If R-12 comes in contact with the skin, it may cause frostbite. This injury should be treated as any other case of frostbite. Immerse the affected part in a warm bath for about 10 minutes, then dry carefully. DO NOT rub or massage the affected area.

Although R-12 is generally classed as nontoxic, it IS poisonous in high concentrations such as might occur from excessive R-12 leakage in a confined or poorly ventilated space. If a person should be overcome by R-12 remove him IMMEDIATELY to a well-ventilated place and get medical attention at the earliest opportunity. Watch his breathing. If the person is not breathing, begin artificial respiration.

CHAPTER 12

AIR CONDITIONING

Air conditioning is a field of engineering dealing with the design, construction, and operation of equipment used in establishing and maintaining desirable indoor air conditions. It is the science of maintaining the atmosphere of an enclosure at any required temperature, humidity, and purity. As such, air conditioning involves the cooling, heating, dehumidifying, ventilating, and purifying of air.

This chapter covers the principal factors involved in the conditioning of air, the type of equipment used in ventilating, cooling and heating the air, and general information concerning the maintenance of air conditioning equipment.

PURPOSES OF AIR CONDITIONING AND RELATED FACTORS

One of the chief purposes of air conditioning is to keep the ship's crew comfortable, alert, and physically fit. The air of various compartments must be of the right temperature, have the proper moisture content, have contamination held within an acceptable level, be circulated properly, and have the correct proportion of oxygen. The human body cannot long maintain a high level of efficiency under adverse conditions.

The comfort and fitness of the crew is not the only immediate purpose of air conditioning. Mechanical cooling or ventilation must also be provided for AMMUNITION SPACES, to prevent deterioration of ammunition components; for GAS STORAGE SPACES, to prevent excessive pressure buildup in containers and contamination from leakage in the space; and for ELECTRICAL/ELECTRONIC EQUIPMENT SPACES, to limit ambient (encompassing) temperature to that specified for the equipment.

The principal factors which must be considered in connection with achieving the objectives of air conditioning are discussed in this chapter.

HUMIDITY

Vapor content of the atmosphere called HUMIDITY, has a great influence on human comfort. The common expression, "It isn't the heat, it's the humidity," indicates the recognition of the discomfort producing effects of moisture-laden air in hot weather. Extremely low moisture content also has undesirable effects on the human body. The measurement and control of the moisture content of the air is an important phase of air conditioning engineering. In order to understand this phase of air conditioning engineering, you should become familiar with the information given in the following paragraphs.

Saturated Air

The air holds varying amounts of water vapor, and, as temperature rises, the amount of moisture that the air can hold increases. But for every temperature there is a definite limit as to the amount of moisture that the air is capable of holding. When air attains the maximum amount of moisture which it can hold at a specific temperature, it is said to be saturated.

The saturation point is usually called the dew point. If the temperature of saturated air falls below its dew point, some of the water vapor in the air must condense to water. The dew that appears on foliage in the early morning when there is a drop in temperature is such a condensation. The "sweating" of cold water pipes is the result of water vapor from the air condensing on the cold surface of the pipes.

Absolute and Specific Humidity

The amount of water vapor in the air is expressed in terms of the weight of the moisture. The weight is usually given in grains (7000 grains equal 1 pound). Absolute humidity is the weight in grains of water vapor per cubic foot of

air. Specific humidity is the weight in grains of water vapor per pound of air. (The weight of water vapor refers only to moisture in the vapor state, and not in any way to the moisture that may be present in the liquid state, such as rain, or dew.)

Relative Humidity

Relative humidity is the ratio of the weight of water vapor in a sample of air to the weight of water vapor that same sample of air would contain if saturated, at the existing temperature. This ratio is usually stated as a percentage. For example, when air is fully saturated, its relative humidity is 100 percent. When air contains no moisture at all, its relative humidity is zero percent. If air is half saturated, its relative humidity is 50 percent.

As far as comfort and discomfort resulting from humidity are concerned it is the relative humidity and not the absolute or specific humidity that is the important factor. This can be easily understood from the discussion that follows.

Moisture always travels from regions of greater wetness to regions of less wetness, just as heat travels from regions of higher temperature to regions of lower temperature. If the air above a liquid is saturated, the two are in equilibrium and no moisture can travel from the liquid to the air; that is, the liquid cannot evaporate. If the air is only partially saturated, some moisture can travel to the air; that is, some evaporation can take place.

If the specific humidity of the air is 120 grains per pound, it is the actual weight of the water vapor in the air. When the temperature of the air is 76° F, the relative humidity is then nearly 90 percent—that is, the air is nearly saturated. At such a relative humidity, the body may perspire freely but the perspiration does not evaporate rapidly; thus a general feeling of discomfort results.

However, if the temperature for the air were 86° F, the relative humidity would then be only 64 percent. That is, although the absolute amount of moisture in the air is the same, the relative humidity is lower, because at 86° F the air is capable of holding more water vapor than it can hold at 76° F. The body is now able to evaporate its excess moisture and the general feeling is much more agreeable, even though the temperature of the air is 10° higher. (The cooling effect is brought about by the absorption of latent heat during the evaporating process.)

In both examples, the specific humidity is the same, but the ability of the air to evaporate liquid moisture is quite different at the two temperatures. This ability to evaporate moisture is directly indicated by the relative humidity. It is for this reason that the control of relative humidity is of extreme importance in air conditioning.

HEAT OF THE AIR

The heat of the air is considered from three standpoints—differentiated as sensible, latent, and total heat.

SENSIBLE HEAT is the heat that changes the temperature of a substance (air) when added to or removed from it. Sensible heat changes can be measured by the household, or dry-bulb thermometer.

Air always contains more or less water vapor. Any water vapor in the air contains the LATENT HEAT OF VAPORIZATION. (Remember that the amount of latent heat present has no effect upon the temperature of the air, as read on a dry-bulb thermometer.)

Any mixture of dry air and water vapor contains both sensible and latent heat. The sum of the sensible heat and the latent heat in any sample of air is called the TOTAL HEAT of the air.

TEMPERATURES

When testing the effectiveness of air conditioning equipment and when checking the humidity of a space, two different temperatures are generally considered. These are the dry-bulb and wet-bulb temperatures.

Measurement of Temperatures

The DRY-BULB TEMPERATURE is the temperature of the sensible heat of the air, as measured by an ordinary thermometer. Such a thermometer in air conditioning engineering is referred to as a dry-bulb thermometer because its bulb is dry, in contrast with the wet-bulb type next described.

The WET-BULB TEMPERATURE is best explained by a description of a wet-bulb thermometer. It is an ordinary thermometer, with a loosely woven cloth sleeve or wick placed around its bulb and then wet with water. The

water in the sleeve or wick is caused to evaporate by a current of air at high velocity. This evaporation withdraws heat from the thermometer bulb, lowering the temperature a number of degrees. The difference between the dry-bulb and the wet-bulb temperature is called the wet-bulb depression. The wet-bulb temperature is the same as the dry-bulb when the air is saturated (that is, when evaporation cannot take place). The condition of saturation, however, is unusual, and a wet-bulb depression is normally expected.

The wet-bulb and dry-bulb thermometers are usually mounted side by side on a frame, to which a handle or short chain is attached so that the thermometers may be whirled in the air, thus providing a high-velocity air current that promotes evaporation. Such a device is known as a SLING PSYCHROMETER. When using the sling psychrometer, whirl it rapidly, at least four times per second. Observe the wet-bulb temperature at intervals. The point at which there is no further drop in temperature is the wet-bulb temperature for that space.

MOTORIZED PSYCHROMETERS are provided with a small motor-driven fan and dry cell batteries. Motorized psychrometers are generally preferred and are gradually replacing sling psychrometers.

Relationships Between the Temperatures

The definite relationships between the three temperatures should be clearly understood. These relationships are:

1. When the air contains some moisture but is not saturated, the dew-point temperature is lower than the dry-bulb temperature, and the wet-bulb temperature lies between them.
2. As the amount of moisture in the air increases, the differences between the dry-bulb temperature and wet-bulb temperature become less.
3. When the air is saturated, all three temperatures are the same.

BODY HEAT BALANCE

Ordinarily the body remains at a fairly constant temperature of 98.6° F. It is very important that this body temperature be maintained, and since there is a continuous heat gain from interior processes, there must also be a continuous outgo to maintain a balance. Excess heat must be absorbed by the surrounding air or lost by radiation. As the temperature and humidity of environment vary, the body automatically regulates the amount of heat which it gives off. However, this ability to adjust to varying environmental conditions is limited. Furthermore, although the body may adjust to certain atmospheric conditions, it may do so with a distinct feeling of discomfort. The discussion which follows will help you understand how atmospheric conditions affect the body's ability to maintain a heat balance.

Body Heat Gains

The body gains heat (1) by radiation, (2) by convection, (3) by conduction, and (4) as a by-product of physiological processes that take place within the body.

The heat gain by radiation comes from our surroundings, but since heat always travels from regions of higher temperature to regions of lower temperature, the body receives heat from those surroundings that have a temperature higher than body surface temperature. The greatest source of heat radiation is the sun. Indoor heat radiation is gained from heating devices, operating machinery, hot steam piping, etc.

The heat gain by convection comes from currents of heated air only. Such currents of air may come from a galley stove or an engine.

The heat gain by conduction comes from objects with which the body, from time to time, is in contact.

Most of the body heat comes from within the body itself. Heat is being continuously produced inside the body by the oxidation of foodstuffs and by other chemical processes, by friction and tension within the muscle tissues, and by other causes as yet not completely identified.

Body Heat Losses

There are two types of body heat losses: loss of sensible heat, and loss of latent heat. Sensible heat is given off by three methods: (1) radiation, (2) convection, and (3) conduction. Latent heat is given off in the breath and by evaporation of perspiration.

The body is usually at a higher temperature than that of its surroundings, and therefore radiates heat to bulkheads, decks, and equipment. This action is called heat radiation loss. The

temperature of the air does not influence this radiation, except as it may alter the temperature of such surroundings.

The heat loss by convection occurs when the heat is carried away from the body by convection currents, both by the air coming out of the lungs and by exterior air currents.

The heat loss by conduction is caused by bodily contact with colder objects or substances. Since the body is usually at a higher temperature than that of its surroundings, it gives up heat by conduction through physical contact with its surroundings.

When the air temperature and relative humidity are not too high and when the body is not too active, the body gets rid of its excess heat by radiation, convection, conduction, and a slight amount of perspiration. When engaged in work or exercise, the body develops much more internal heat, and perspiration increases. If the relative humidity is low, perspiration rapidly evaporates. As the perspiration evaporates, the body loses additional heat (latent heat of vaporization). However, if the relative humidity of the air is high, the moisture cannot evaporate, or it does so at a slow rate; hence the excess heat cannot be removed by evaporation, and discomfort follows.

The amount of heat given off by the body varies according to the body's activity. When seated at rest, the average adult male gives off about 380 Btu per hour. Doing routine work on a ship, a man gives off an average of 500 to 600 Btu per hour.

For light work on a ship, particularly on a submarine, research has shown that the total amount of body heat loss is divided as follows: About 45 percent by radiation, 30 percent by convection and conduction, and 25 percent by evaporation.

EFFECT OF AIR MOTION

In perfectly still air, a layer of air adjacent to the body absorbs the sensible heat given off by the body and increases in temperature. The layer of air also takes up the water vapor given off by the body, and thus increases in relative humidity. The body is thus surrounded by an envelope of air which is at a higher temperature and relative humidity than the ambient air, and the amount of heat which the body can lose to this envelope is less than that amount it can lose to the ambient air. If the air is set in motion past the body, the envelope is continually broken up and replaced by the ambient air, and the heat loss from the body is increased. When the increased heat loss improves the heat balance, the sensation of a "breeze" is felt; when the increase is excessive, the sensation of a "draft" is felt.

SENSATION OF COMFORT

From the foregoing discussion, it is evident that the three factors—temperature, humidity, and air motion—are closely interrelated in their effects upon comfort and health. In fact, a given combination of temperature, humidity, and air motion will produce the same feeling of warmth or coolness as a higher or lower temperature in conjunction with a compensating humidity, and air motion. The term given to the net effect of these factors is known as the EFFECTIVE TEMPERATURE. This temperature cannot be measured by any instrument, but may be found on a special psychrometric chart when the dry-bulb and wet-bulb temperatures and air velocity are known.

Though all of the combinations of temperature, relative humidity, and air motion of a particular effective temperature may produce the same feeling of warmth or coolness, they are not all equally comfortable. It has been found that a relative humidity below 15 percent produces a parched condition of the mucous membranes of the mouth, nose, and lungs, and increases susceptibility to disease germs. A relative humidity above 70 percent causes an accumulation of moisture in clothing. For best health conditions, a relative humidity ranging from 40 to 50 percent for cold weather, and from 50 to 60 percent for warm weather, is desirable. An overall range from 30 to 70 percent is acceptable.

VENTILATION EQUIPMENT

Since proper circulation is the basis for all ventilating and air conditioning systems and of related processes, information dealing with the means of circulating air will be considered first. The sections which follow contain information on equipment used to supply, circulate, and distribute fresh air, and to remove used, polluted, and overheated air.

Fans used on Navy ships in conjunction with supply and exhaust systems may be divided into two general classes; axial flow and centrifugal. Most fans in duct systems are of the axial flow

type because axial flow fans generally require less space for installation.

Centrifugal fans are generally preferred for exhaust systems handling explosive or hot gases. The motors of these fans, being outside the air stream, cannot ignite the explosive gases. The motors are subject to overheating to a lesser degree than are motors of vane-axial fans. If the temperature of the gases being handled is very high, the heat transmitted to the motor, through the shaft, may cause trouble.

VANE-AXIAL FANS (fig. 12-1) are high pressure fans and are generally installed in duct systems. They are provided with vanes at the discharge end to straighten out rotational air motion caused by the impeller. The motors for these fans are cooled by the air in the duct. They will overheat if operated with all air over the fan shut off.

TUBE-AXIAL FANS are low pressure fans and are usually installed without duct work. However, they do have sufficient pressure for a short length of duct.

CENTRIFUGAL FANS (part A of fig. 12-2) are used primarily for exhausting explosive or hot gases. However, they may be used in lieu of axial flow fans if they work in better with the arrangement or if their pressure-volume characteristics suit the installation better than an axial flow fan. Centrifugal fans are also used in the standard fan coil assemblies.

The PORTABLE FANS (part B of fig. 12-2) with flexible airhoses, are used aboard ship to ventilate compartments after painting, to exhaust flammable or toxic gases from closed spaces and tanks, and to cool hot spots around machinery during repairs.

Most of the portable fans are of the axial flow type, driven by electric, "explosion-proof" motors. On ships carrying gasoline, a few air turbine-driven centrifugal fans are normally provided. Greater confidence is placed in the explosion-proof characteristics of these fans.

The WATERPROOF VENTILATOR, shown in figure 12-3 consists of an outer housing, an inner ventilator shaft extending up to the outer housing, and a bucket-type closure supported over the ventilator shaft by a compression spring. The bucket is provided with drain tubes extending into a sump between the ventilator shaft and the outer housing. The sump is provided with scupper valves, which drain onto the weather deck.

The ventilator operates automatically, and is normally open. Small quantities of water which enter the ventilator fall into the bucket and drain out through the drain tubes and scuppers. In heavy seas, when water enters the bucket faster than it drains out, the weight of water forces the bucket down against the top of the ventilator shaft. Thus, a watertight seal is formed and maintained until sufficient water drains out to permit the force of the spring to raise the bucket to the open position. Operating gear is generally provided, also, to permit a manual closing of the ventilator. With slight variations in construction, this ventilator is used for both the supply and exhaust of air.

BRACKET FANS are used in hot weather to provide local circulation. These fans are usually installed in living, hospital, office, commissary, issuance, and berthing spaces. Where mechanical cooling is employed, bracket fans are sometimes used to facilitate proper circulation and direction of cold air.

EXHAUSTS are used to remove heat and objectionable odors at their source. Machinery spaces, laundries, and galleys are but a few of the spaces aboard ship where exhausts are used.

Most exhausts on Navy ships are mechanical although natural exhaust is sometimes provided on small craft and in ships' structures.

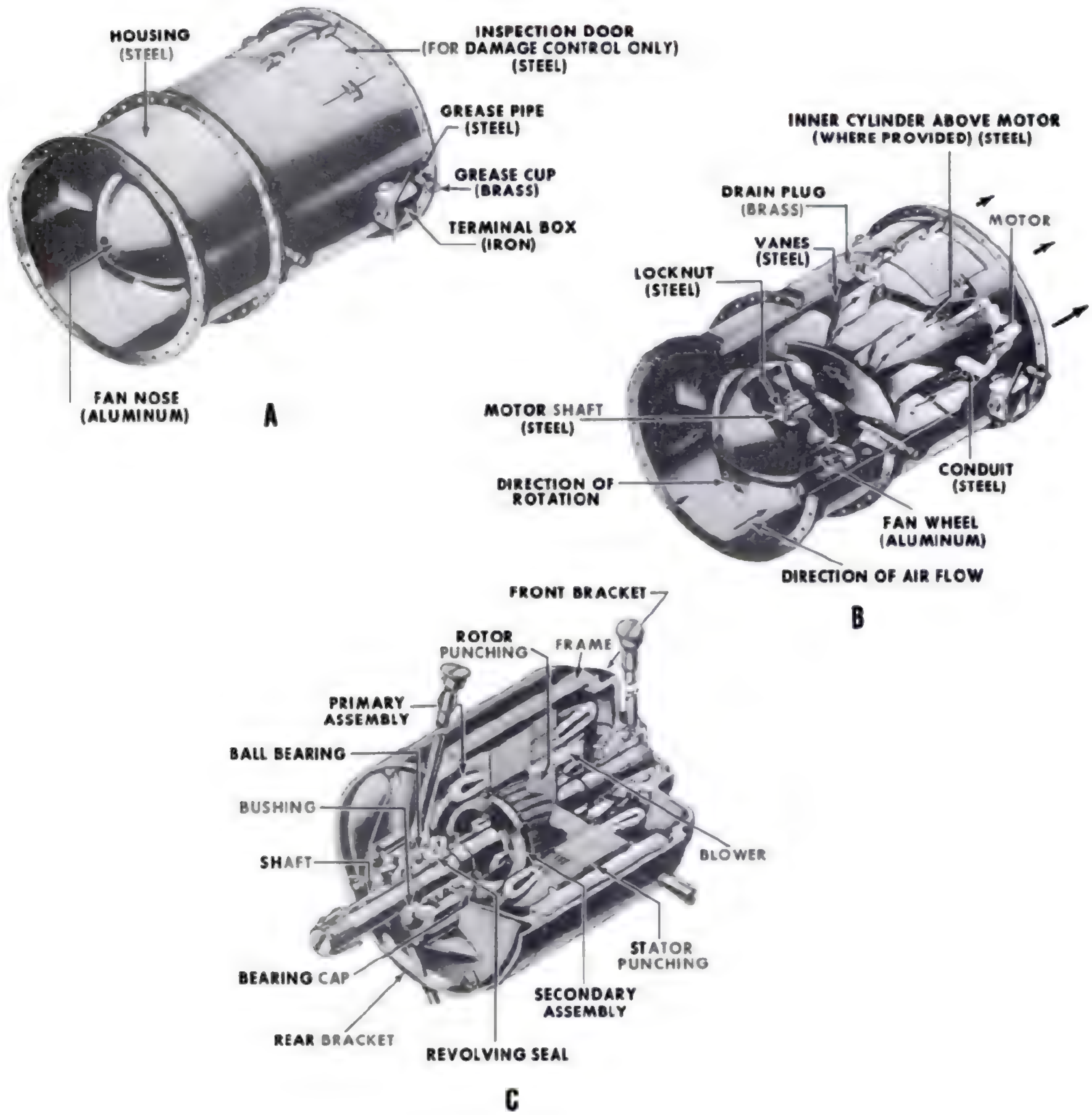
MECHANICAL COOLING EQUIPMENT

On the latest combatant ships, practically all parts of the ship, except machinery spaces, are air conditioned. To determine what equipment will most effectively dehumidify and lower the temperature of compartment air, the Navy has tested several types of air cooling systems. Basically, these systems are refrigerant systems, their design and construction depending on the characteristics of the cooling element circulated through the system and on the principle of operation utilized.

There are, in general, three types of mechanical air-cooling systems used aboard Navy ships: the refrigerant circulating system, the chilled water circulating system, and the self-contained air conditioners.

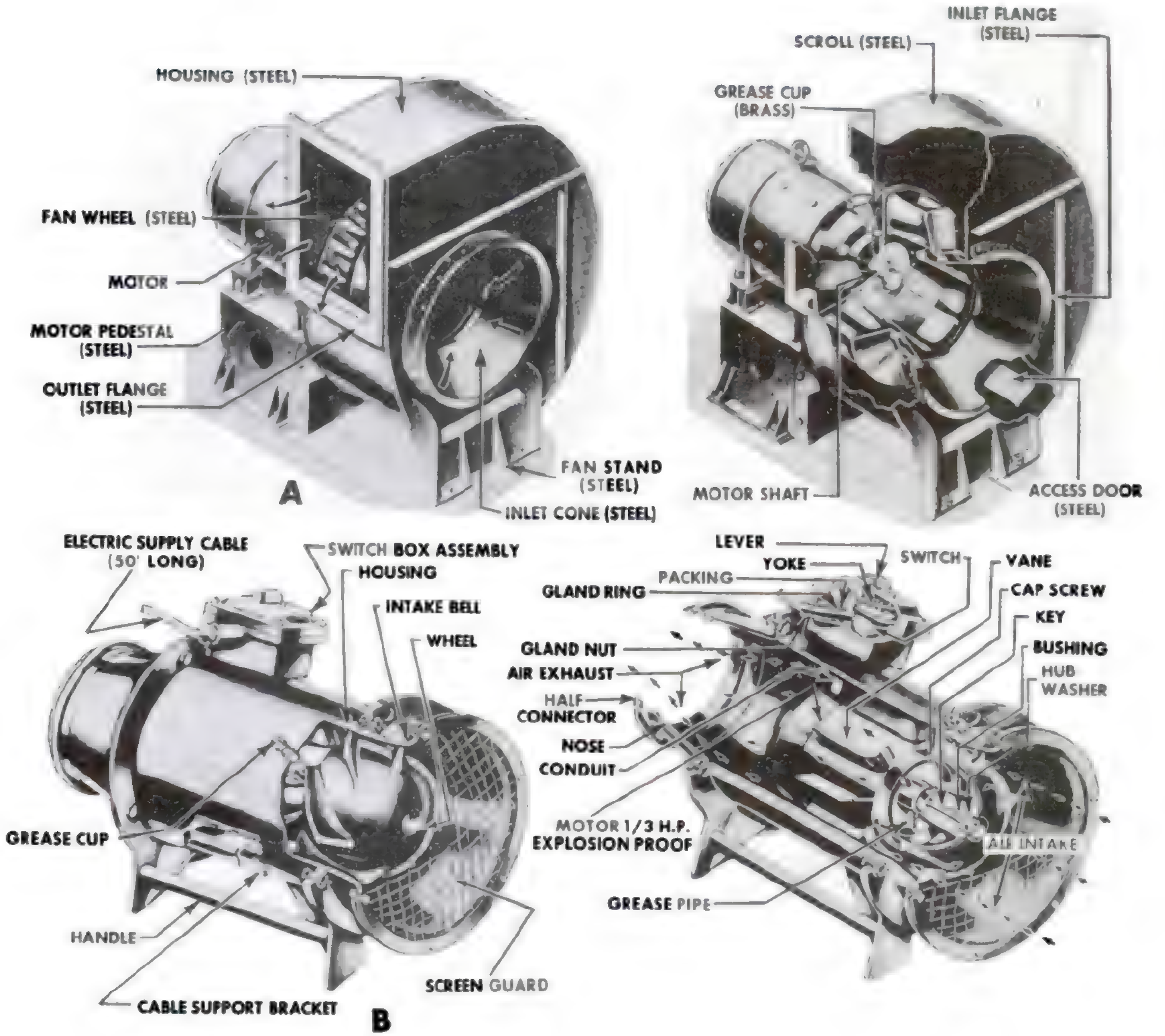
REFRIGERANT CIRCULATING SYSTEMS

The refrigerant circulating system (fig. 12-4) is essentially a shipboard refrigerating plant,



47.106

Figure 12-1.—Vane-axial ventilating fan: A. Exterior view. B. Cutaway view. C. Cutaway view of the fan motor.

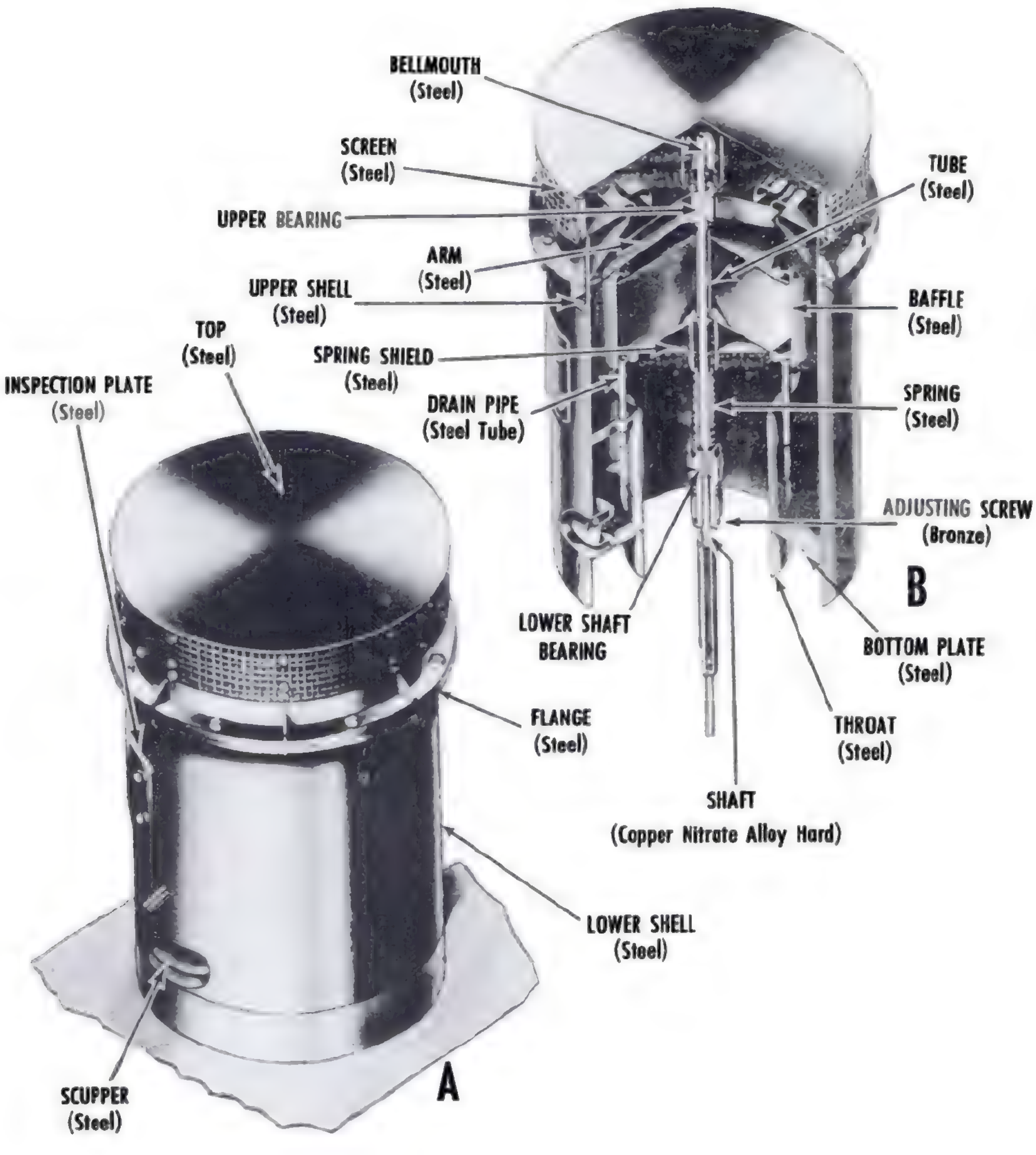


47.107

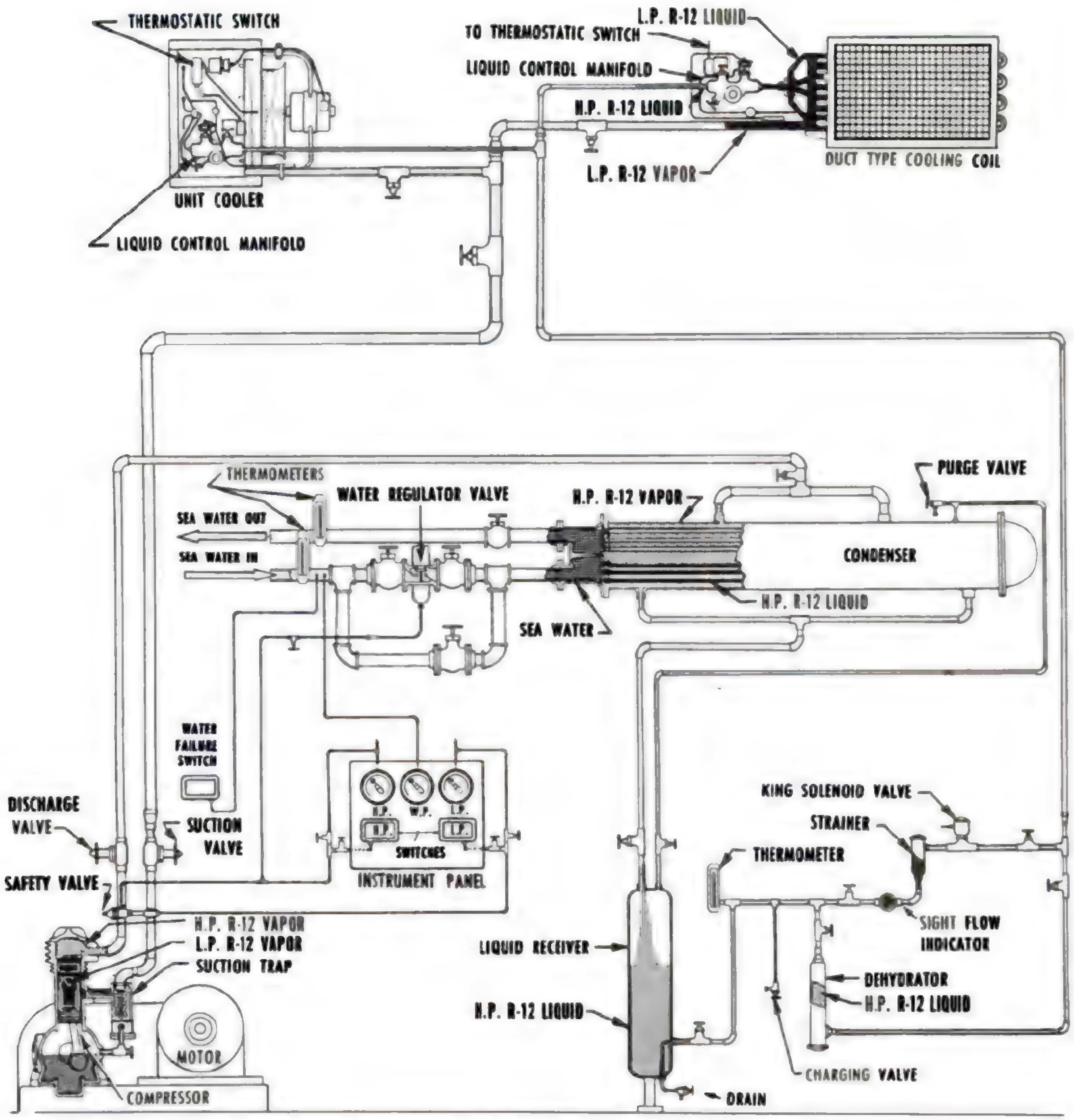
Figure 12-2.—Miscellaneous ventilating fans: A. Centrifugal fan. B. Portable axial fan.

consisting of a compressor, condenser, cooling coils, fan, air filter, and the necessary controls. (R-12 is used as the refrigerant and cooling agent in systems of this type.)

Starting from the space to be cooled, the air conditioning cycle is as follows: The hot, moist air from the space is drawn through a duct, or passageway, where it mixes with fresh air drawn in from the outside. The fan may be so located as to blow air over the cooling coil; the refrigerant inside the coil cools the coil surface. The cold surface absorbs the heat from the air passing over it and condenses the excess moisture. The moisture drips off into a pan below the coil and is carried away by drain piping. The cool, dry air leaving the coil is blown into the compartment to be air conditioned, where it absorbs the excess heat and moisture



47.108
Figure 12-3.—Waterproof ventilators: A. Exterior view. B. Cutaway view.



47.110
Figure 12-4. — Typical shipboard refrigerant-circulating air conditioning system.

in the space, and is then returned to the cooling coil. Air is exhausted from the space to allow for fresh air being drawn into the space. The cooling coils are installed in the ventilation ducts leading to the spaces to be air conditioned. Automatic and manual controls are added to regulate the operations of the air conditioning equipment.

In general, the machinery and piping arrangements of the ship's refrigeration system and of the R-12 air conditioning system are similar.

Operating suction pressures and evaporator temperatures used in air conditioning systems are higher than those in refrigeration systems. The difference in suction pressure results in a corresponding effect on the rated capacity of the compressor.

In refrigerant-circulating air conditioning plants the thermostatic expansion valves are normally of the external equalizing type. The internal equalizing port between the valve outlet and the spring chamber is eliminated; instead there is an opening, through the valve, directly into the spring chamber. By means of copper tubing the spring chamber is connected to the cooling coil, beyond the point of greatest pressure drop. In air conditioning plants, the external equalizer is required in instances where the pressure drop through the cooling coils is 2-1/2 psi or more, or when multicircuit coils are used.

CHILLED WATER CIRCULATING SYSTEMS

There are two air conditioning systems currently in use, which circulate chilled water to the spaces to be cooled. One type operates on the vapor compression cycle and R-11 or R-12 is used as the primary refrigerant; the type of primary refrigerant used will depend on the size of the unit and the type of compressor installed. The other type of system, used on some ships, operates on the absorption cycle and uses water as the primary and secondary refrigerants; lithium bromide is used as an absorbent.

Vapor Compressor Unit

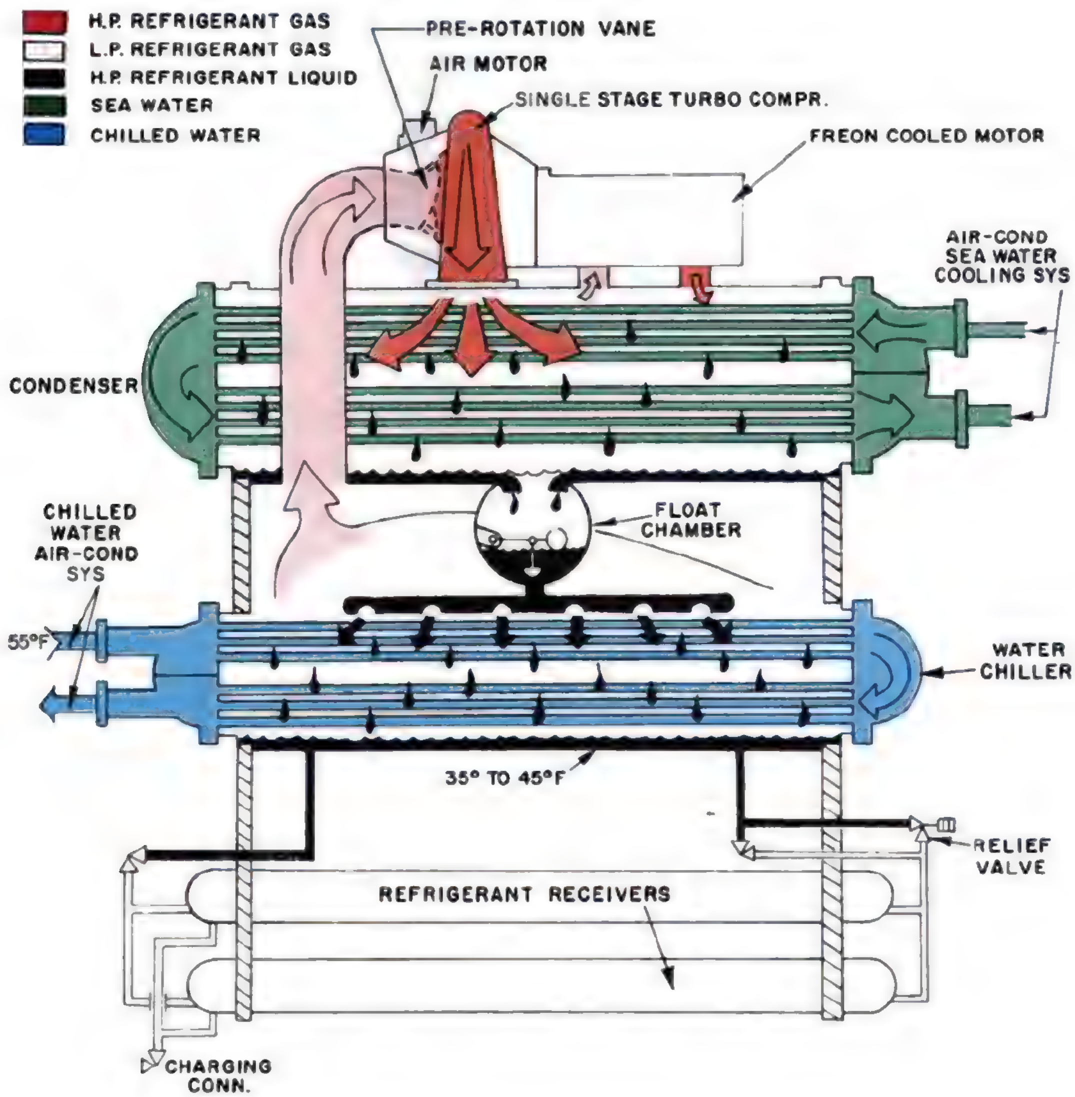
The vapor compression chilled water circulating system differs from a direct expansion air conditioning system in that the air conditioning is accomplished by a secondary refrigerant (chilled water) which is circulated to the various cooling coils. Heat from the air conditioned space is absorbed by the chilled water and is removed from the water by the primary refrigerant system in the water chiller. In larger capacity air conditioning systems, the compressor may be a centrifugal type that uses R-11 as the primary refrigerant rather than a reciprocating type that uses R-12 as the primary refrigerant.

The operating cycle of the centrifugal refrigerating machine (fig. 12-5) is basically the same as most refrigerating machines except for the method of compression. The refrigerant gas is pressurized in the turbo compressor, and then flows to the condenser where it is condensed by sea water flowing through the condenser tubes. The liquid refrigerant then flows from the bottom of the condenser through a float operated control valve to the water chiller. The refrigerant in the chiller becomes a vapor as it absorbs heat from the fresh water circulating through the chiller tubes. The refrigerant vapor then enters the suction side of the turbo compressor to repeat the cycle.

The compressor motor, with its electrical windings cooled by the refrigerant, is sealed to prevent refrigerant leakage to the atmosphere.

The following controls and safety devices are typical of those installed on a refrigerating system, using a centrifugal compressor: (Control settings are approximate since they will vary with differences in design.)

1. The CONDENSER GAGE indicates the pressure corresponding to the condensing temperature.
2. The COOLER GAGE indicates the pressure corresponding to the evaporator temperature.
3. The OIL GAGE indicates the lube oil pressure within the lubricating system.
4. The HIGH PRESSURE SWITCH is actuated by the condenser pressure and is set to cut in at 5 psig and to cut out at 15 psig.
5. The COMPRESSOR LOW LUBE OIL PRESSURE SWITCH is actuated by the compressor oil pressure and is set to cut in at 12 psig and to cut out at 6 psig.
6. The CONDENSER WATER PRESSURE FAILURE SWITCH is actuated by the sea water pressure and is set to cut in at 15 psig and to cut out at 5 psig.
7. The CHILLED WATER DIFFERENTIAL PRESSURE FAILURE SWITCH is actuated by the chilled water pressure and is set to cut in at 20 psig and to cut out at 16 psig.



158.130
Figure 12-5.—Vapor compressor unit.

8. The REFRIGERANT TEMPERATURE CONTROL SWITCH has its thermal bulb located in the cooler. It is set to cut out at 30° F and to cut in at 40° F.

9. The CHILLED WATER TEMPERATURE CONTROL SWITCH has its thermal bulb located in one of the tubes in the chilled water cooler. It is set to cut out at 42° F and to cut in at 50° F.

10. The OIL HEATER START AND STOP BUTTON controls the electric heater located in the oil pump chamber of the compressor. The oil heater limits the amount of refrigerant absorption during shutdown. The heater should be turned on when the compressor is not running and turned off when the plant is operating.

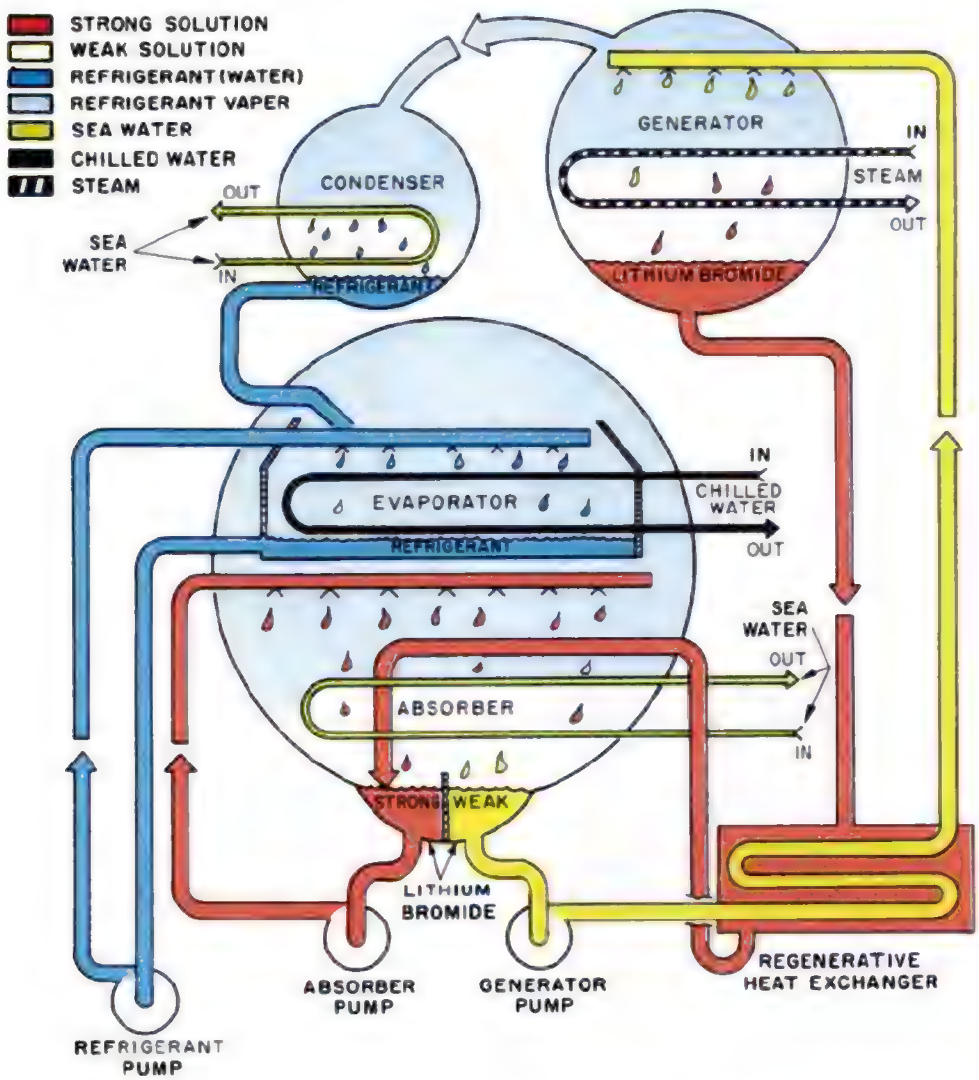
Lithium Bromide Absorption Unit

The lithium bromide absorption unit which operates on the absorption cycle differs from that which operates on the compression cycle

in that it employs heat energy instead of mechanical energy to effect the change in the conditions necessary to complete the refrigeration cycle. The compressor is supplanted by steam heat. The lithium bromide absorption unit vaporizes the water refrigerant, at a high vacuum to remove heat from the air-conditioning chilled-water system. See figure 12-6. The entire unit is evacuated to approximately 29.8 inches vacuum. At this vacuum, water will boil at 35° F.

Water is sprayed into the evaporator by the refrigerant pump and impinges on the chilled water coils. The water vaporizes, thus removing heat from the chilled water in the coils, and reduces the temperature of the chilled water.

Lithium bromide solution has the property of absorbing water vapor. The water vapor from the evaporator flows to the absorber section where it is absorbed by the lithium bromide solution. Sea water circulating through coils in the absorber section removes the heat of absorber. Continued absorption of water vapor dilutes the lithium bromide solution and decreases its efficiency. The generator pump circulates



158.131
Figure 12-6.—Lithium bromide absorption unit.

the WEAK lithium bromide solution through a regenerative heat exchanger to the generator. Steam coils in the generator heat the solution, thus removing the water and restoring the required concentration to the solution. The STRONG solution then returns to the absorber via the regenerative heat exchanger where it is cooled as it preheats the WEAK solution. The water vapor passes from the generator to the condenser where it is cooled and condensed by sea water and returned to the evaporator for reuse as refrigerant.

SELF-CONTAINED AIR CONDITIONERS

Self-contained air conditioners are now being installed on some ships that were built without air conditioning. This type air conditioner is built with the entire unit in one metal cabinet. Installation is simple; only the mounting brackets, electrical leads, and the cooling water lines are necessary for complete installation.

Compressing elements in the self-contained air conditioners are usually of the hermetic type (motor and compressor are contained in a welded steel shell). Repairing the compressor or motor aboard ship is impractical; the assembly should be replaced as a unit.

Compressor discharge pressures vary from 120 psig to 200 psig, suction pressures vary from 30 psig to 65 psig. The temperature DROP of the air across the cooling coil is usually 16° to 18° F.

Self-contained air conditioners use a thermal expansion valve, similar to the type used on the ship's refrigeration plant. However, these expansion valves are non-adjusting type valves, built with a fixed setting by the manufacturer. If an expansion valve does not function properly, it should be removed and replaced with a similar valve.

The high pressure and low pressure switches are set and sealed at the factory. The only adjustable controls are the water regulating valve and the thermostat. The principle of operation and the adjustment of the water regulating valve are the same as for the one used on the ship's refrigerating plant.

To set the thermostat, the following procedure may be used:

1. In the air conditioned compartment, place a thermometer at a point where the desired room temperature is of most importance.
2. Turn thermostat control to the coldest position.
3. When the desired temperature is reached, slowly turn the thermostat control toward the "warmer" position until the compressor stops.

FAN-COIL ASSEMBLIES

The fan-coil assembly is a new piece of equipment presently (1966) being specified for new construction and for some ships in the fleet that are scheduled for the installation of central air conditioning units. Fan-coil assemblies are prefabricated air conditioners, consisting of a fan and motor, air filters, coil bypass damper, thermal and acoustical insulation, and a chilled water coil enclosed in a metal cabinet, used in conjunction with a chilled water system for air conditioning spaces on all types of ships.

The fan-coil assembly may be used in lieu of a fan room aboard ship. The assembly may be installed with or without ductwork. The assembly has outlets on the top, front, and ends of the cabinet. The outlets may be used singly or in multiples for zone air distribution with ductwork or for free air delivery without ductwork. A cooling coil bypass is also provided. When the air conditioner is installed outside the space being served, ductwork between the air conditioned space and the cooling coil bypass inlet is provided by the installing activity. This is to ensure that return air is used for bypass and not replenishment air.

The fan used in the assembly is a belt-driven centrifugal fan. The belt drive permits a varying capacity to fit the application depending on the use or extent of ductwork.

The cooling coil has copper tubes, fins, and headers. The coil is eight rows deep in direction of air flow and is provided with vent and drain cocks. The vent and drain are accessible through a removable access panel.

The assembly is provided with a fixed bypass manual locking type damper mounted as an integral part of a removable end panel. All working mechanisms of the damper are enclosed inside the cabinet to prevent adjustment of the damper from the exterior of the cabinet without the panel being removed.

Provision is made to permit access to and removal of the fan, fan drive, motor, and cooling coil through removable end panels. The removable end panels are interchangeable on each assembly. A front access opening is also provided to permit servicing, adjustment, and removal of the motor, fan bearings, pulleys, and

belts from the front of the cabinet. The removable panels and access openings are gasketed and airtight under normal operating conditions.

For servicing the air filters, access openings are provided on each end of the cabinet.

AIR CONDITIONING EQUIPMENT OPERATING RECORD

A daily operating record is maintained for all air conditioning equipment except self-contained air conditioners. Figure 12-7 shows the back side of the form, used to record compartment temperatures and chilled water pressures and temperatures. The front side of the operating record is the same as that shown in figure 11-15A. The main difference in filling in the front side of the form is that compressor suction and discharge temperatures and pressures will be higher for air conditioning plants than for refrigeration plants.

HEATING EQUIPMENT

VENTILATION HEATERS (fig. 12-8) are installed in duct systems and are used wherever practical because of savings in weight, space, and piping. These heaters are built to withstand considerable shock and have standard connections to simplify piping. The copper tubes, through which the steam flows, are arranged in a single row.

Two different types of coil arrangements are employed. Part B of figure 12-8 shows the "S" arrangement with the tubing serpentined. The S-type is used in small size heaters. For large size heaters the S-type is not efficient; a small amount of uncondensed steam is left in the drain end portion of the tube.

Part C of figure 12-8 shows a "T" arrangement which has a copper tube within a tube (a 3/8-inch distributing tube inside a 5/8-inch

NAVSEC 9590/1 (REV. 12-69) (BACK)

REFRIGERATION/AIR CONDITIONING EQUIPMENT OPERATING RECORD

TIME	WATER CHILLER SUPPLY PRESS PSIG	WATER CHILLER SUPPLY TEMP °F	WATER CHILLER RETURN PRESS PSIG	WATER CHILLER RETURN TEMP °F	COMPARTMENT NO 2-41-2-C LMTS 78-82	NO 2-43-3-C LMTS 78-82	NO 2-51-1-C LMTS 78-82	NO 1-52-0-L LMTS 78-82	NO 1-57-2-L LMTS 78-82	NO 2-58-2-L LMTS 78-82	NO 1-59-1-C LMTS 78-82	NO 1-61-2-C LMTS 78-82	REMARKS
0200	45	47	45	56	80	80	80	79	78	79	84	80	0030 Readjusted
0400	45	46	45	55	78	79	79	79	78	79	80	79	thermostatic
0600													switch in
0800													compartment 1-159-1-C
1000													
1200													
2000													
2200													
2400													

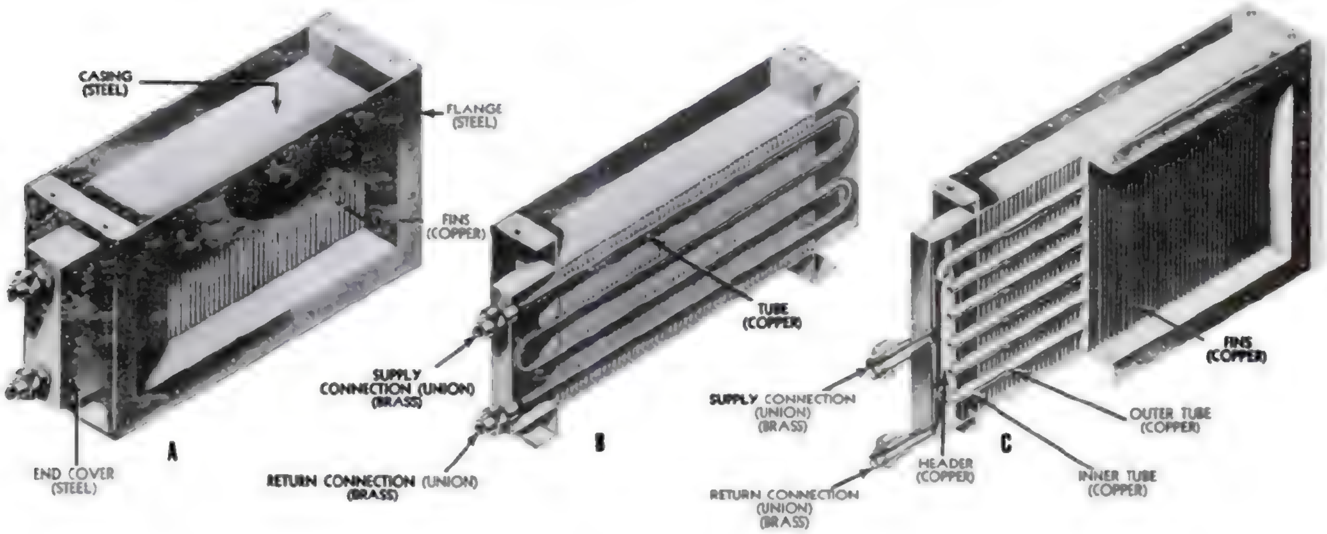
GENERAL REMARKS

0045 Started No. 1 Compressor
0115 Secured No. 2 Compressor

PLATE NO. 10506 (2)

47.104.2

Figure 12-7.—Air conditioning equipment operating record (back), NAVSEC 9590/1.



47.111

Figure 12-8.—Ventilation heater: A. Exterior view of S-type heater. B. Tube arrangement of S-type heater. C. Tube arrangement of T-type heater.

outer tube). Steam pressures up to 150 psi may be used in these heaters.

Large ventilation supply systems, excepting those serving machinery spaces, are provided with a PREHEATER at or near the weather intake. By locating the heater near the intake, the duct temperature is kept high enough to avoid condensation during cold weather operation.

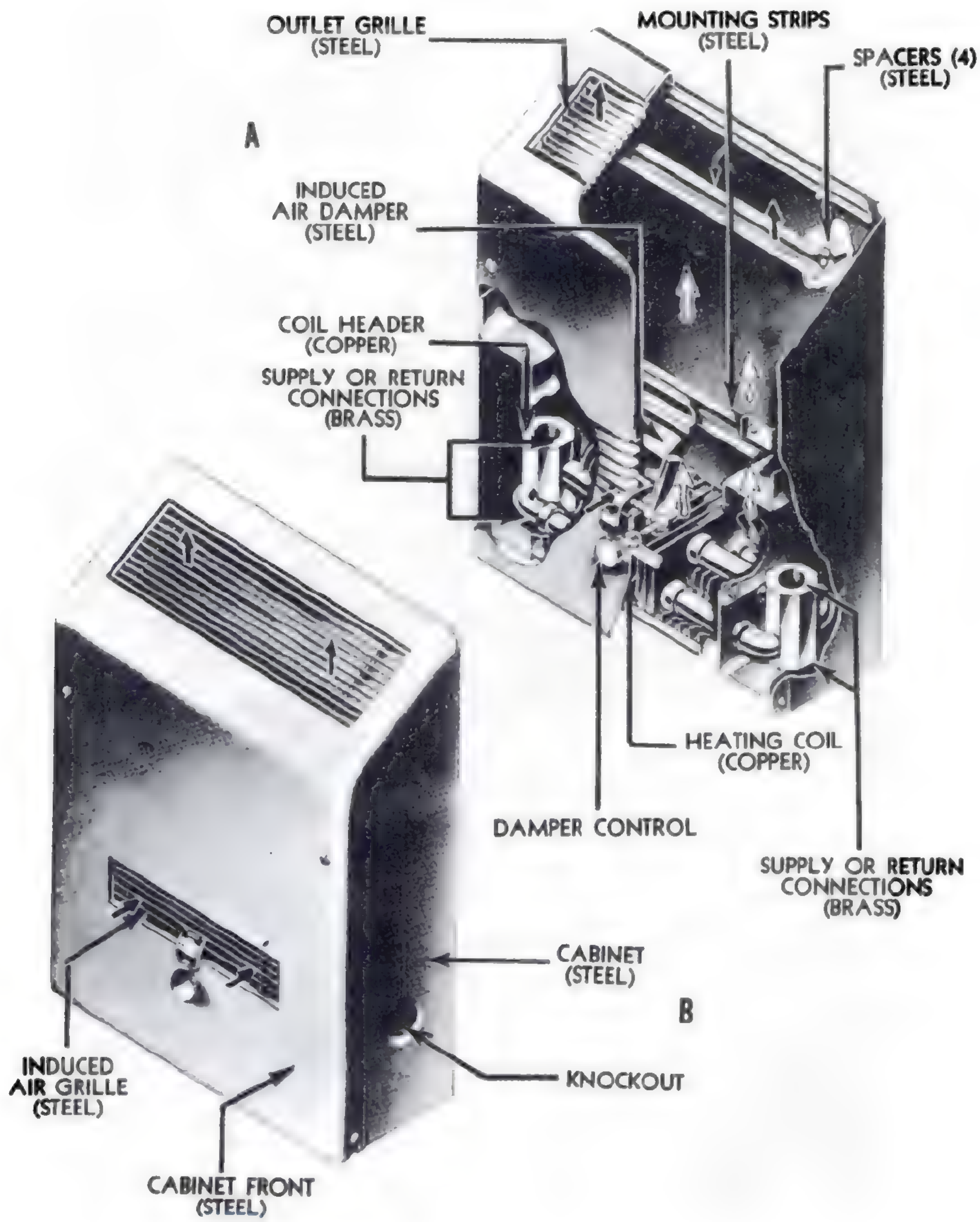
If the system serves spaces that are maintained at a specified temperature (generally 65° F) a REHEATER (or reheaters) is also provided. In recirculating cooling systems reheaters are usually provided to maintain specified space temperatures during cold weather operation.

The preheater has a thermostatic control arranged to prevent freezing of the coil and to maintain a certain duct air temperature (usually between 45° and 65° F). Steam is supplied through two regulating valves, either in a single body or as separate valves. One valve is orificed to pass 25 percent of the required steam and is controlled by a thermostat in the duct on the weather side of the heater. It is factory set at 35° F. The other valve is orificed to pass 75 percent of the required steam and is controlled by a thermostat in the duct on the discharge side of the heater.

Reheaters supply either single spaces or zones. Zones are made up of spaces that are expected to have similar heat loads. Reheaters are generally controlled by room thermostats. In a few installations, reheaters are controlled by duct type thermostats. In recirculating cooling systems on the newer ships, the reheaters utilize a constant supply of steam to reheat air to any zone which would be overcooled.

In small ventilation systems employing short duct runs where one heater will produce the required temperature rise, the COMBINATION HEATER is used alone. Combination heaters may also be used with reheaters where it is desired that the system supply more than one space but where the combination heater is sufficient to maintain the required temperature rise in one of the spaces.

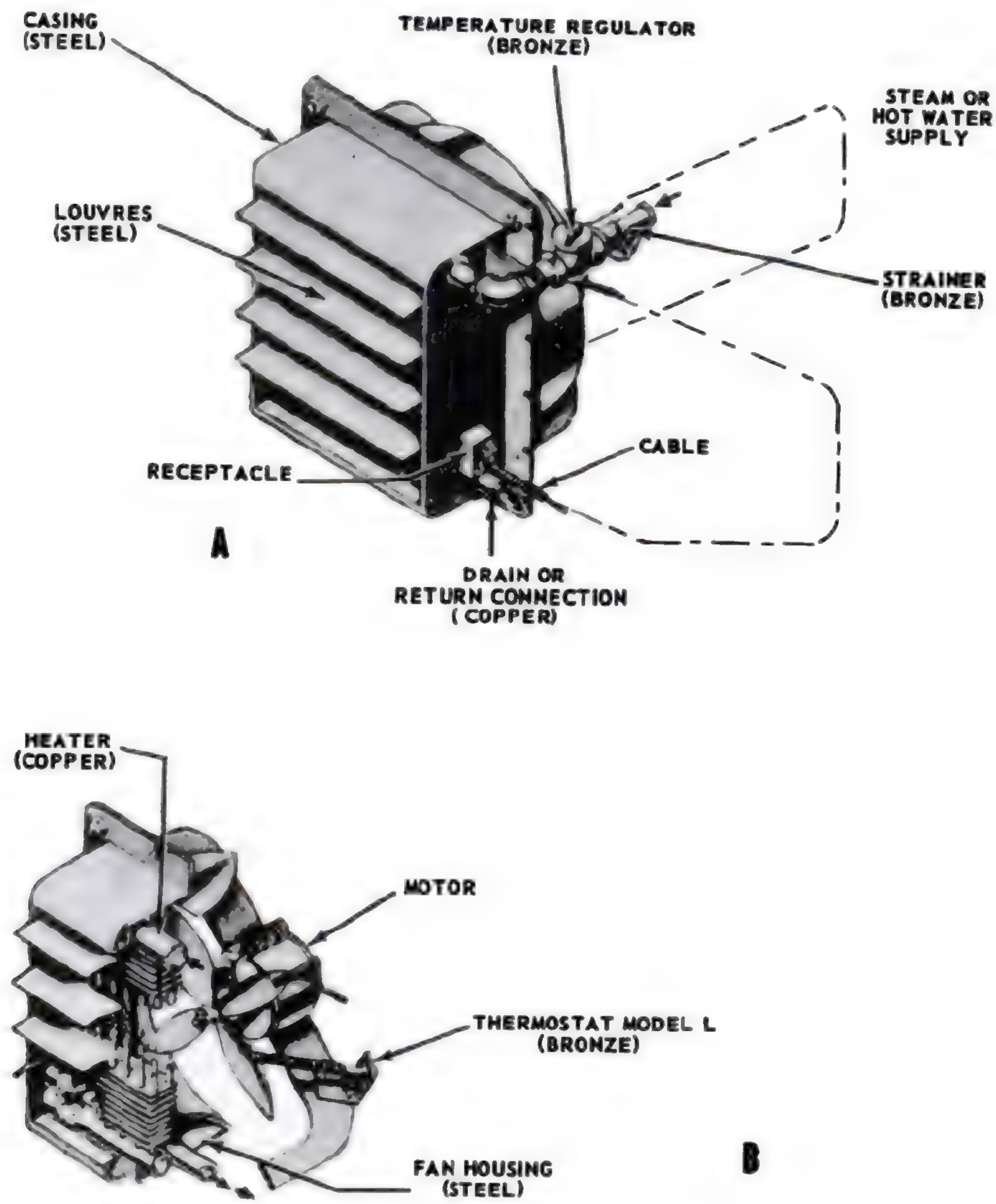
CONVECTOR HEATERS (fig. 12-9) are installed in small spaces or in spaces which are not fitted with mechanical supply ventilation. These heaters have a high heating capacity for their size and weight, are considerably smaller than radiators or pipe-coils of the same capacity, and will withstand severe shock. A steam pressure up to 150 psi may be used in the heaters, or a forced hot water system may be employed. When convector heaters are used with steam pressure between 25 and 50 psi, temperature differentials at different levels in the room are reduced. The heating is regulated with the air bypass damper in the front part of



47.112
Figure 12-9.—Convector heater: A. Cutaway view. B. Exterior view.

the heater. The cabinets are generally of steel, though they may be (if desired) of copper of a nonmagnetic construction.

UNIT HEATERS, illustrated in figure 12-10, are actually ventilation heaters installed separately with their own fans. They are used in special cases such as when the amount of supply ventilation is too small to provide sufficient heat through ventilation heaters, or where there is no mechanical ventilation supply and the heat requirements exceed the capacity of convector heaters. They can be used with either steam pressure up to 150 psi or with forced hot water systems. Composite parts of the heaters include the heat transfer surface (fins and tubes), fan,



47.113
Figure 12-10.—Unit heater: A. Exterior view. B. Cutaway view.

thermostatic control valve, strainer, trap, and directional louvers.

ELECTRICAL HEATERS are used for spaces located at a considerable distance from the steam piping system. They are built in many types and designs.

MAINTENANCE OF AIR CONDITIONING EQUIPMENT

To ensure proper operation of any air conditioning system, periodic inspection and maintenance is absolutely necessary. Each ship should have an organization responsible for the maintenance of ventilating, heating, and cooling equipment.

MAINTENANCE OF VENTILATION EQUIPMENT

Shipboard ventilation must serve not only to supply, circulate, and distribute fresh air, but also to remove the used, contaminated, and overheated air from the various spaces. If the ventilation equipment fails to perform its functions properly, conditions may be created which will jeopardize the health or life of crew members. Therefore, the individuals responsible for inspection and maintenance must be thoroughly familiar with the ventilation equipment.

A shipboard ventilation system and its constituent parts cannot be isolated and separated from other component systems in a complete air conditioning system. For example, the air duct distribution system of a ship may be utilized for other systems used in cooling, heating, and dehumidifying the ship's atmospheric air. In addition to ducts, a ventilation system may include weather openings, screens, filters, fans, gratings, closures, heaters, cooling coils, venturi tubes, dampers, and terminals. Obviously, if a ventilation system is to function effectively, it is essential that all of its various units be kept clean and in satisfactory operating condition. To maintain a ventilating system in the best condition requires the observance of applicable precautionary measures, and the adherence to prescribed maintenance procedures.

Guarding Against Obstructions to Ventilation

Such items as swabs, deck gear, and trash stowed in fan rooms or ventilation trunks not only restrict air flow but also increase dirt and odors taken inboard. Ventilation terminals must never be used for stowage. Wet clothing secured to ventilation terminals increases the moisture content of the compartment air, and restricts the air flow. Stowage arrangements should be such that ventilation weather openings are never restricted.

Do not use gauze or similar material as a filter over an air supply terminal. Gauze may aid in preventing the passage of dirt but it also serves an obstruction to the passage of air. The fact that filtering is necessary indicates that the system needs cleaning. The amount of dirt entering a space from the ventilation system can be most effectively reduced by keeping the ducts clean. If it becomes necessary to place a filter in an air supply system, place the filter at the intake rather than supply terminals.

Keeping the System Clean

Dirt accumulations in a ventilation system not only restrict the flow of air but also create a serious fire hazard. In a clean duct the cooling effect of the metal tends to act as a flame arrester, but an accumulation of foreign matter within a duct becomes a potential source of combustion. One method of reducing the amount of dirt and combustible matter which may be carried into a ventilation system is to wet down the areas in the vicinity of the air intakes before sweeping.

Since a great volume of air passes through or over the elements of a ventilation system, dirt will collect in the various units in spite of precautionary measures. The greatest accumulations of dirt will be within trunks and ducts where it is not readily noticeable. Therefore, periodic inspections and a definite service procedure are necessary to keep the system clean.

Cleaning Filters

Navy standard air filters have pressure taps on each side of the filter bank. By use of a portable differential pressure gage, the pressure drop across the filter may be quickly read. When the pressure drop increases to three times that of a clean filter, the filter must be cleaned. Ships are provided with spare filters so that a clean one may be substituted for the dirty one. A systematic procedure may be set up for cleaning all filters on the ship.

Where there are only a few filters aboard ship, they may be cleaned in the galley dishwashing machine. Ships having a sufficient number

of filters to justify the space, expense, and weight are supplied with special cleaning sinks. In either case, filters are washed with dishwashing compound, used in accordance with the current dishwashing instructions.

If a special cleaning sink is used, proceed as follows:

1. Place filters in the wire basket, one filter deep, with the dirty side up.
2. Fill sink with fresh water, cut steam into sink to heat and agitate the water. (Most of the lint and dirt will rise to the top and pass off with the overflow.)
3. When filters are clean, cut off the steam and drain the sink.
4. Refill sink with fresh water, cut steam into sink, and rinse filters.
5. Reoil filters.

Navy standard air filters have a thin film of oil applied to the wires. The oil film retains fine particles of dirt and lint. After each washing, the filters may be reoiled by spraying with filter oil. Spray guns furnished for oiling air filters must not be used for any other purpose, to avoid the possibility of contaminating the filters with toxic, flammable, or odor laden materials.

Flame arresters and grease filters may be cleaned in the manner prescribed for air filters, however, special care must be taken in rinsing. Flame arresters and grease filters SHOULD NEVER BE OILED.

MAINTENANCE OF COOLING EQUIPMENT

Since air conditioning systems are in many ways similar to refrigeration plants, much of the information concerning refrigeration, given in this training course, is equally applicable to air conditioning equipment. To ensure proper operation of any R-12 air conditioning plant, periodic inspections must be made of compressors, valves, motors, cooling coils, air filters, and other installed equipment. Most of these maintenance items are covered by the Planned Maintenance System and will be scheduled accordingly.

CHAPTER 13

STEAM OPERATED DISTILLING PLANTS

Naval ships must be self-sustaining as far as the production of fresh water is concerned. The large quantities of fresh water required aboard ship for boiler feed, drinking, cooking, bathing, and washing make it impracticable to provide storage tanks large enough for more than a few days supply. Therefore, all naval ships depend upon distilling plants to meet the requirements for large quantities of fresh water of extremely high chemical and biological purity.

This chapter deals with the general description and operation of steam operated naval distilling plants. Evaporation followed by condensation is the means used to produce distilled water from raw sea water. Boiler feed water must be of high purity to maintain high heat transfer and prevent excessive scaling and corrosion.

All shipboard distilling plants not only perform the same basic function but also perform this function in much the same way. The distillation process consists of heating sea water to the boiling point and condensing the vapor to obtain fresh water, DISTILLATE. Each plant has a heating section to produce water vapor, a condenser to condense the vapors from the evaporators, a preheater to preheat the feed water, and a cooler to cool the distillate. This chapter provides information on steam operated plants of the submerged tube, vertical basket, and flash types.

SUBMERGED TUBE DISTILLING PLANTS

Submerged tube distilling plants are divided into three types: Soloshell double effect (fig. 13-1), triple effect, (fig. 13-2), and two-shell double effect (fig. 13-3).

A brief discussion of the differences between the three principal types of low-pressure distilling plants will give you a general idea of the plants you may work with. These three types are the Soloshell double-effect, the two-shell double-effect, and the three-shell triple-effect plants.

SOLOSHELL DOUBLE-EFFECT PLANTS

Most soloshell double-effect units have capacities of 12,000 gallons per day or less. However, some soloshell units of 20,000 gpd capacity are in use. The Soloshell double-effect units consists of a single cylindrical shell mounted with the axis horizontal. A vertical partition plate, parallel to the axis, divides the shell into two evaporator chambers. Each of these chambers has a separate removable tube bundle bolted to the front head of the shell (the first- and second-effect evaporator tube bundles). The first-effect vapor feed heater is built into the upper part of the first-effect shell, and also has a removable tube bundle bolted to the front head.

The distilling condenser (condensing and feed-heating sections) is built into the upper part of the second-effect shell. This unit does not have a removable tube bundle. The tube sheets project beyond the front and rear heads of the shell, providing access for cleaning or replacing tubes. The air ejector condenser is a separate unit, mounted on brackets on the evaporator shell. The distillate cooler is also in a separate shell and may be located wherever convenient for the necessary piping connections.

One type of 20,000 gpd capacity Soloshell double-effect plant was installed on light and heavy cruisers. Two such plants are installed when it is necessary to furnish an overall capacity of 40,000 gpd. In such plants, the vertical partition separating the first and second effects is at right angles to the axis of the cylinder. The first-effect vapor feed heater is in the upper part of the first-effect shell; the distilling condenser is in the upper part of the second-effect shell, and the air ejector condenser is mounted on the main evaporator shell.

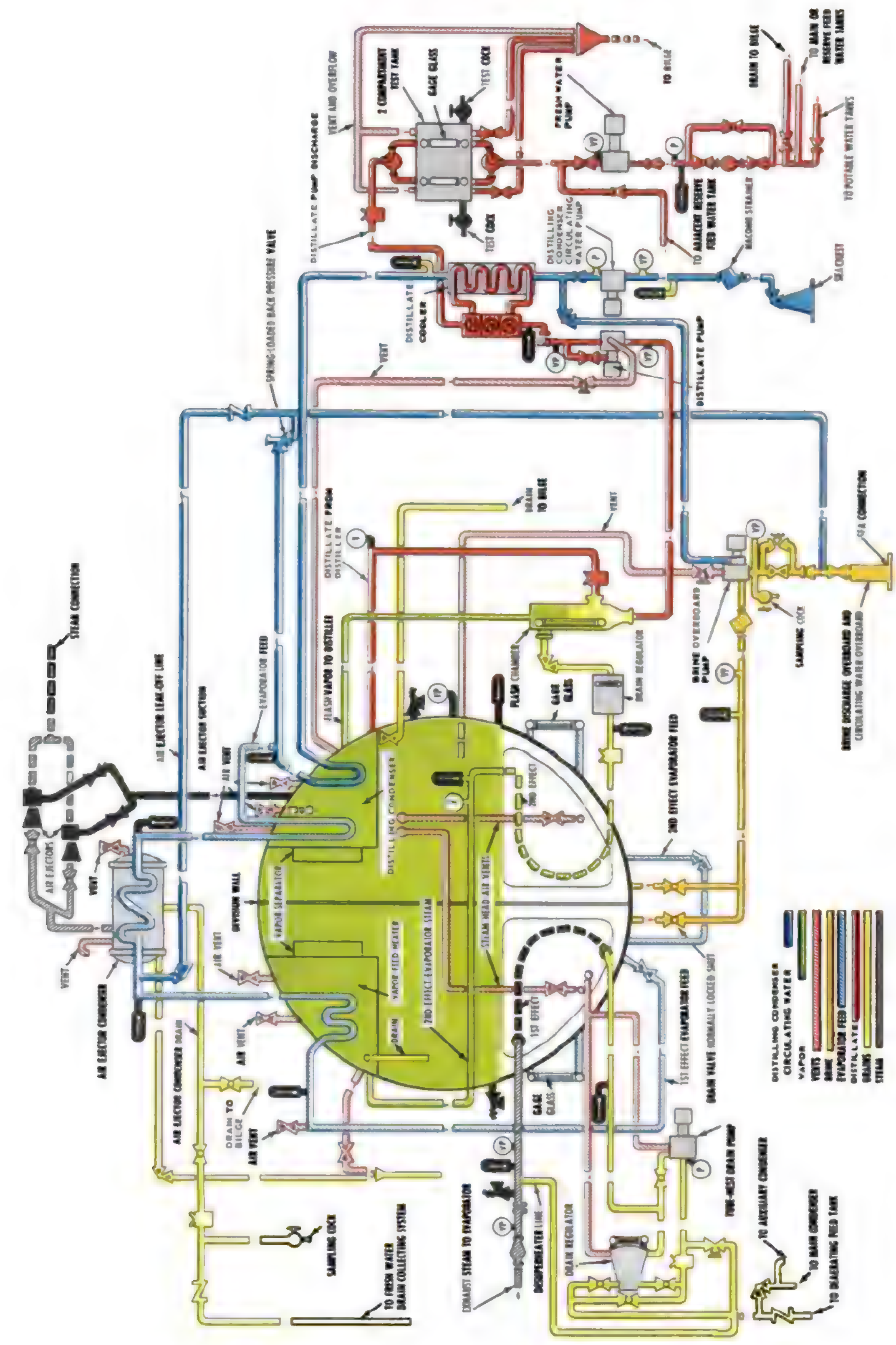


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Figure 13-1.—Schematic drawing of a double-effect distilling plant.

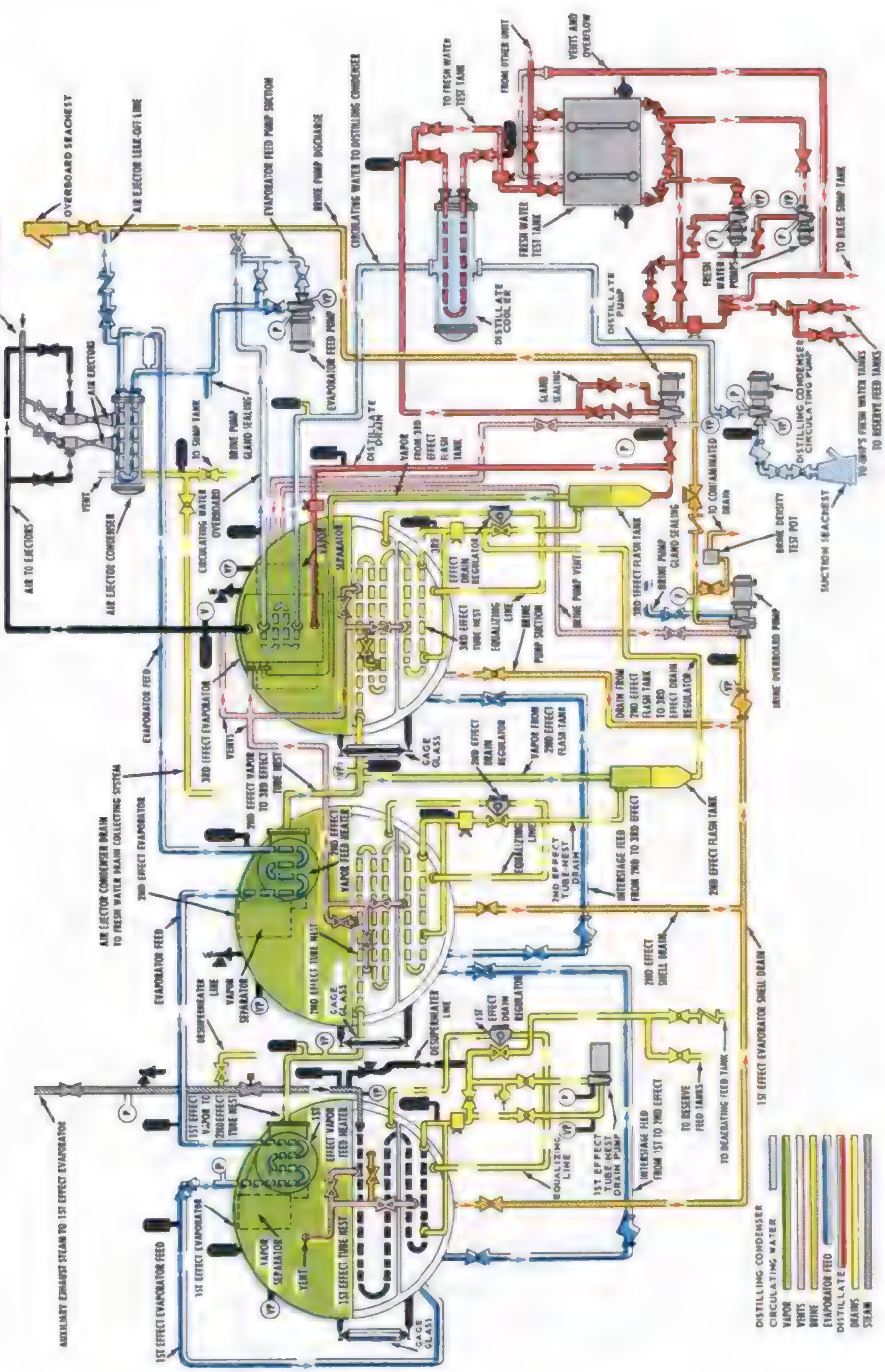

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Figure 13-2.—Schematic drawing of a triple-effect distilling plant.

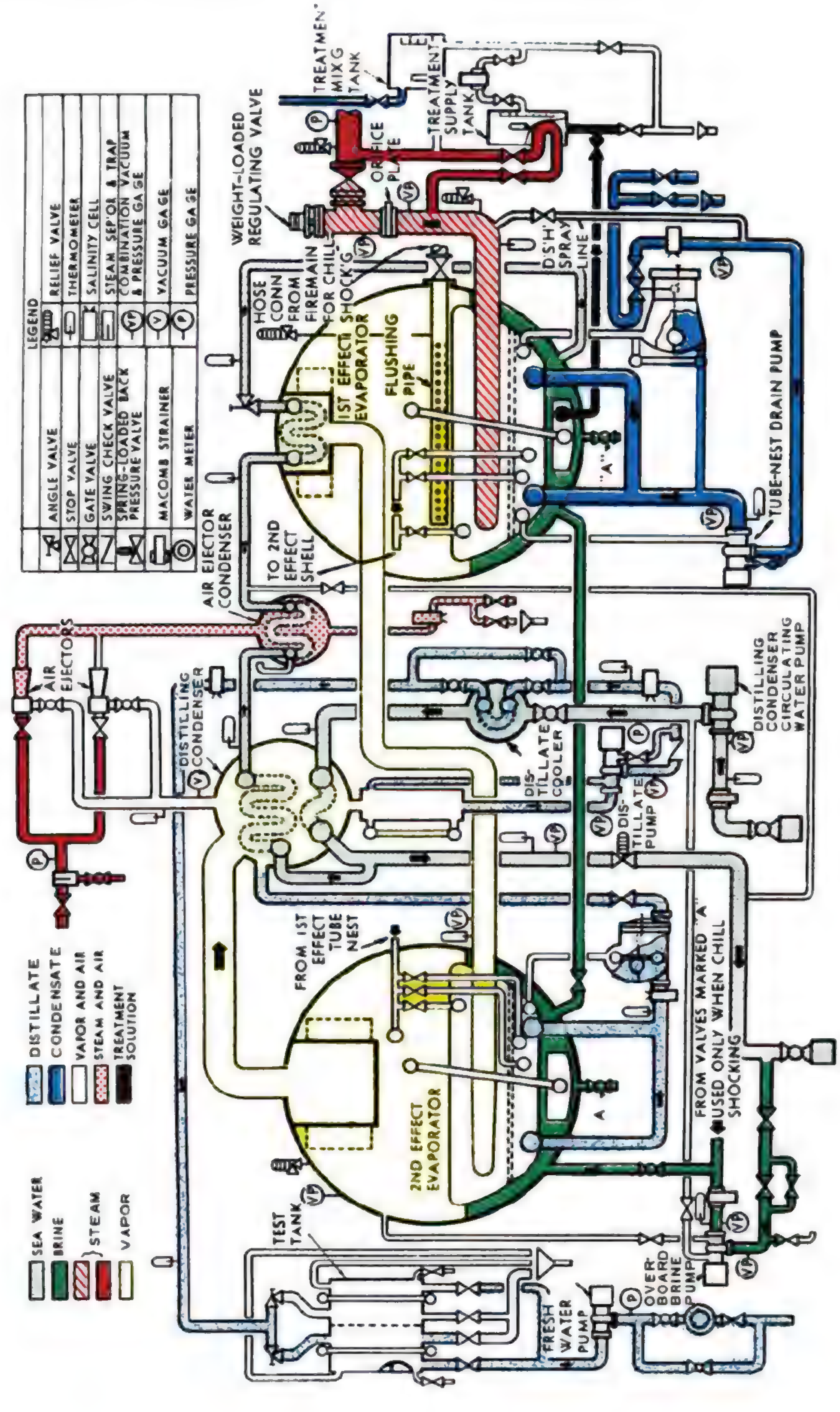

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Figure 13-3. —Schematic drawing of a two-unit double-effect distilling plant.

The distillate cooler is mounted similarly to that in the smaller Soloshell plants.

The distilling plant's steam is obtained from the auxiliary exhaust line through a weight-loaded or an air controlled regulating valve. This valve is set to maintain a constant steam pressure of 1 to 5 psi above the orifice to the tube nest of the first-effect evaporator. A pressure gage is installed ahead of the regulating valve. A relief valve, a thermometer, and a compound gage are installed on the steam head of the evaporator tube nest in order to keep a check on the steam supply.

In passing through the regulating valve, the auxiliary exhaust steam is reduced to a pressure of 5 psi. The steam then passes through an orifice plate (control orifice) in the steam line between the regulating valve and the inlet to the first-effect tube nest. This control orifice is designed to control the amount of steam entering the plant to an amount required for the plant's designed output of distilled water. A change in the size of the orifice alters the plant output.

Because of the throttling effect in passing through the control orifice, the low-pressure steam becomes superheated. The auxiliary exhaust steam is therefore passed through a desuperheating area in the steam line. Desuperheating is accomplished by a spray of hot water piped from the first-effect tube nest drain pump. This water is sprayed into the steam supply line in sufficient quantity to reduce the steam temperature to that required for the pressure existing in the tube nest.

After being desuperheated, the steam passes into the first-effect tube nest. Here the steam gives up its latent heat of vaporization to the feed water surrounding the first-effect tubes. The resulting condensate (condensed steam) from the first-effect tube nest is discharged by the pump to the deaerating feed tank. In an emergency, the condensate may be discharged to the main condensers, the auxiliary turbogenerator condensers, or the fresh water drain collecting system. This condensate is returned to the boiler feed system to help maintain the heat and water content of that system constant.

When a ship is in port or at anchor, the supply of auxiliary exhaust steam may not be sufficient to operate the distilling plant. To overcome this deficiency, steam from the 150 psi system is introduced to the system through an augmenting valve.

Steam generated in the evaporator shells by the evaporation of the feed water is referred to as VAPOR, to prevent confusing it with the steam which is introduced into the first-effect evaporator tubes and is the outside source of heat for the plant. The vapor is separated from the feed water at the water surface and, although the vapor itself is pure, small particles of raw, unevaporated feed water are mixed with it. The particles of feed water are removed from the vapor by a series of baffles above the surface of the water in the evaporator shell, and by additional baffles or vanes in the first-effect VAPOR SEPARATOR. (NOTE: The term feed water as used in this chapter and the following chapter identifies the raw sea water or river water which is used as feed for the evaporator.)

The vapor changes its direction of motion several times in passing around the hooked edges of the baffles and vanes. The hooked edges trap particles of feed water and drain them into pipelines. These pipelines discharge the separated moisture as far away as possible from the vapor separator in the evaporator shell.

After passing through the vapor separator on its way to the second-effect tube nest, the vapor passes through a VAPOR FEED HEATER. Part of the vapor is condensed as it gives up its latent heat to the feed water passing through the tubes of the heater. The remaining vapor and distillate pass together into the tube nest of the second-hand evaporator. Here the first-effect vapor gives up its latent heat in generating vapor from the feed water in the second-effect evaporator shell.

In the second-effect shell, the pressure surrounding the sea water is considerably less than in the first-effect shell. This makes it possible to use the vapor formed in the first-effect shell to boil and vaporize the sea water in the second-effect shell.

The vapor generated in the second-effect shell passes through a vapor separator and into a distiller condenser. The condensing tubes nearest the incoming vapor are utilized as a feed heating section where the vapor is partially condensed; thereby heating the feed water circulating through the condenser tubes. The remainder of the vapor is condensed in the condensing section and is discharged to the test tanks as fresh water.

The distillate formed in the second-effect tubes is discharged through the second-effect

tube nest drain regulator and led to the distiller condenser through the flash chamber.

The distilling condenser circulating water pump takes suction from the sea and discharges the water through the distillate cooler and the distilling condenser. A strainer is installed in the pump suction piping.

The cooling water passes through the shell of the distillate cooler and then through the tubes of the distilling condenser. The cooling water is then discharged overboard through a spring-loaded back-pressure valve set to maintain a back pressure of about 5 psig.

A portion of the sea water discharged from the cooling water circuit is used as feed to the first-effect evaporator. A 5 psi back pressure provides sufficient head to force water through the distilling condenser, air ejector condenser, vapor feed heater, and to the first-effect shell where it enters through perforated internal feed distributing pipes located well below the working water level in the shell.

A portion of the feed water is evaporated after entering the first-effect shell. This increases the density, or salinity, of the remaining portion. This denser or saltier water, commonly referred to as BRINE to distinguish it from sea water, is led into the second-effect shell.

The brine is transferred to the second-effect shell through a pipeline having a manually controlled feed regulating valve installed in it. The higher pressure in the first-effect shell is utilized to force the brine into the second effect, where it is distributed by means of perforated internal feed pipes. (In a triple effect plant, the brine then passes to the third-effect shell through a pipeline and is distributed in a manner similar to that in the second-effect shell of a double-effect plant.)

A brine overboard pump takes suction from the second-effect shell through a Macomb-type strainer, and discharges the brine into the distilling condenser circulating pump overboard discharge line. To permit rapid draining of the first- and second-effect shells as when chill shocking, they have suction connections leading directly to the brine overboard pump. Since these connections are not used in normal operations, they are provided with valves that can be locked closed to prevent accidental opening, which would upset proper operations of the plant.

TWO-SHELL DOUBLE-EFFECT PLANTS

The most commonly used 20,000 gpd double-effect plant is built with two horizontal cylindrical evaporator shells (fig. 13-3), one for each effect, and usually mounted with the axes of the shells parallel. Tube nests for both shells may be removed from the front head. The first-effect vapor feed heater is built into the upper part of the first-effect shell. In this design, the distilling condenser and the distillate cooler are built into separate shells, and usually mounted between the two evaporator shells. The air ejector condenser is also an independent unit and is mounted on one of the two shells.

TRIPLE-EFFECT PLANTS

The triple-effect distilling plant is similar to the double-effect plant except that the triple effect has an intermediate evaporating stage. A standard 20,000 gpd triple-effect plant consists of three horizontal, cylindrical shells set side by side with their axes parallel. The tube bundles can be withdrawn from the front cover of each shell. The first- and second-effect vapor feed heaters are built into the front end of the second- and third-effect evaporator shells. The distilling condenser is contained within the third-effect shell. The air ejector condenser and the distillate cooler are in separate shells and are mounted on the third-effect shell. Figure 13-4 illustrates the internal arrangement of a first-effect evaporator shell of a triple-effect plant.

Another 20,000 gpd triple-effect design consists essentially of three horizontal shells bolted together end to end, with vertical partition plates between each section (shell) to form the three effects. The tube bundles can be withdrawn horizontally through one side of the cylinder. Vapor separators in independent shells are installed in the vapor piping between effects and between the third effect and the distilling condenser. The first- and second-effect vapor feed heaters are in separate shells and are mounted in the piping at the inlet to the second- and third-effect tube bundles, respectively. The two sections of the distilling condenser and the distillate cooler are built into a single shell and independently mounted as space and piping arrangements may permit. The air ejector condenser is also a separately mounted unit.

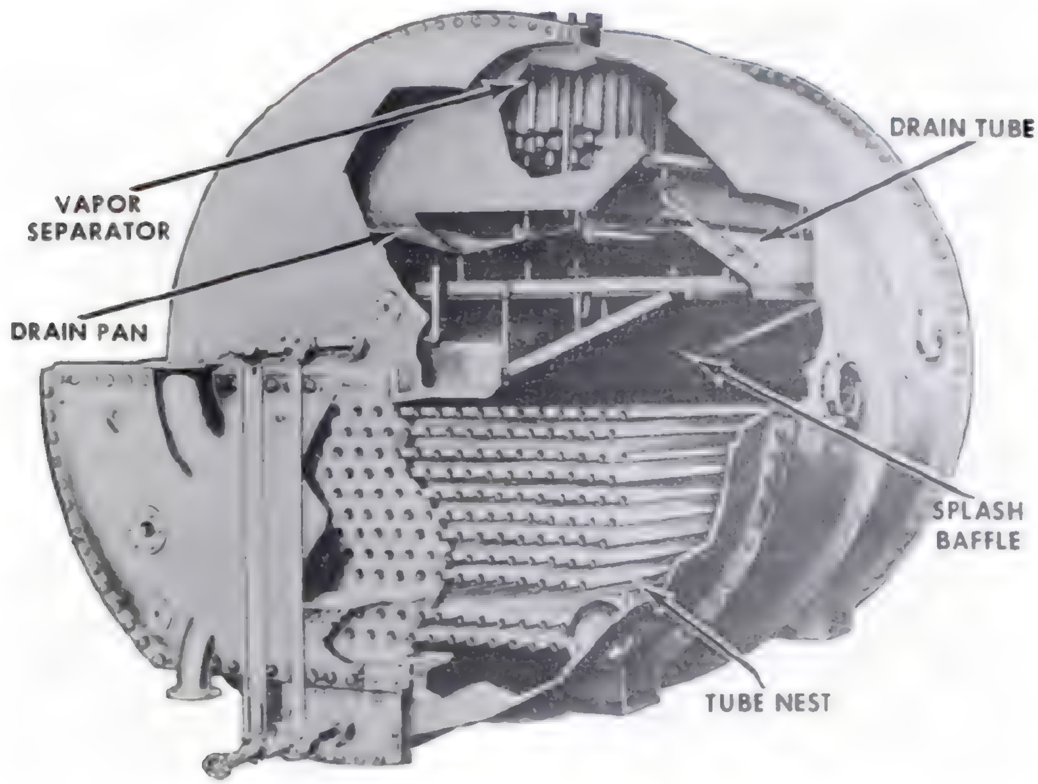

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Figure 13-4.—Internal arrangement of the first-effect shell of a triple-effect distilling plant.

The standard 30,000 gpd triple-effect plant is similar to the standard 20,000 gpd plant, except for the increased size of the units.

There are two types of 40,000 gpd triple-effect plants which may be considered as standard, due to their wide use in naval ships. The first type uses exactly the same arrangement as the standard 20,000 gpd triple-effect plant, with the size of the units and parts increased as necessary for the greater capacity. The second type consists of three horizontal shells, usually mounted side by side with axes parallel. The tube bundles can be withdrawn through the front end of the shells as in the 20,000 gpd two-shell double-effect plant. In this design, both vapor feed heaters and the distilling condenser are built as three independent units, each mounted separately outside the evaporator shells. The air ejector condenser and the distillate cooler are also in independent shells and are separately mounted outside the evaporator shells.

When you compare a low-pressure triple-effect distilling plant with a low-pressure double-effect plant, you will find that:

1. UNITS ADDED to the triple-effect plant include one evaporator shell, one vapor separator, one feed water heater, one feed pump, and several salinity cells. The evaporator feed pump takes suction from the distilling condenser cooling water circuit at a point between the outlet of the condensing section of the distilling condenser and the spring-loaded back-pressure valve.

2. The SALT WATER FEED is piped successively from the first-effect shell to the second- and third-effect shells. The water decreases in heat and increases in density as it progresses from the first to the third effects.

3. The BRINE DISCHARGE is made from the third-effect shell instead of from the second-effect shell.

4. The GENERATING HEAT in the tube nests of the second- and third-effect shells is derived from the vapor created in the preceding shell.

5. The VACUUM is increasingly higher in each successive evaporator shell and in the plant as a whole, as the distance from the air ejector and the distilling condenser is decreased. This higher vacuum, lowering the boiling point, makes it possible to generate vapor with the lower overall temperatures of the sea water or brine and the vapor filled tubes.

The principal parts of a modern low-pressure triple-effect distilling plant include the tube nests, distiller condenser, vapor feed heaters, level controllers, air ejector, flash chamber, air ejector condenser, distillate cooler, and tube-nest drain regulator.

Evaporator Tubes

The evaporator tubes are made of either copper-nickel alloy or copper-zinc-tin alloy (admiralty metal). The tube bundle consists of two sets of tubes—an upper set of either eight or nine rows of horizontal tubing, and a lower set of two or three rows of similar tubing. Tube ends are inserted into and expanded to fit tightly in holes in the front and rear tube sheets (fig. 13-4). Both front and rear tube sheets are provided with flanged heads or cover plates. The internal areas of the tubes and heads thus form the evaporator heating section (tube bundle). The front head and tube sheet are flanged to the front head of the shell cylinder. The rear tube sheet and head, and an intermediate tube supporting plate are supported inside the shell cylinder by rollers which are mounted on rails. This "floating head" design permits unrestricted expansion and contraction of the tube bundles. In addition, this type of construction permits removal of the tube bundles for cleaning.

Distilling Condenser

This condenser consists mainly of a bank of tubes through which the cooling sea water flows, a baffle plate which deflects the water vapor away from the air precooling section, a section of tubes known as the inner heating section, and an outside shell. In standard designs, the condensing unit is generally built into the third-effect shell. The distilling condenser of the Soloshell double-effect plant is built into the upper part of the second-effect shell (fig. 13-1). However, in some distilling plants the condenser is a separate unit, such as that illustrated in figure 13-5.

Vapor Feed Heaters

The number of vapor feed heaters in a distilling plant varies, depending upon the number of effects and the design of the plant. The feed water passes through the tubes in these heaters on its way to the first-effect shell. Vapor from one of the evaporator shells passes into each heater and flows around the heater tubes, thus heating the feed water. A typical vapor feed heater is shown in figure 13-6.

Level Controllers

In practically all of the distilling plants built prior to 1950, the water level in the shell of each effect is controlled by manually regulating the individual feed inlet valves. Many of the plants built since that date, however, are provided with automatic feed-level control devices. These adjustable weir type level controllers (fig. 13-7) are located in the brine discharge from each effect. The feed from each effect to the next is only the amount of brine that spills over the weir and is the excess of feed over evaporation in that effect.

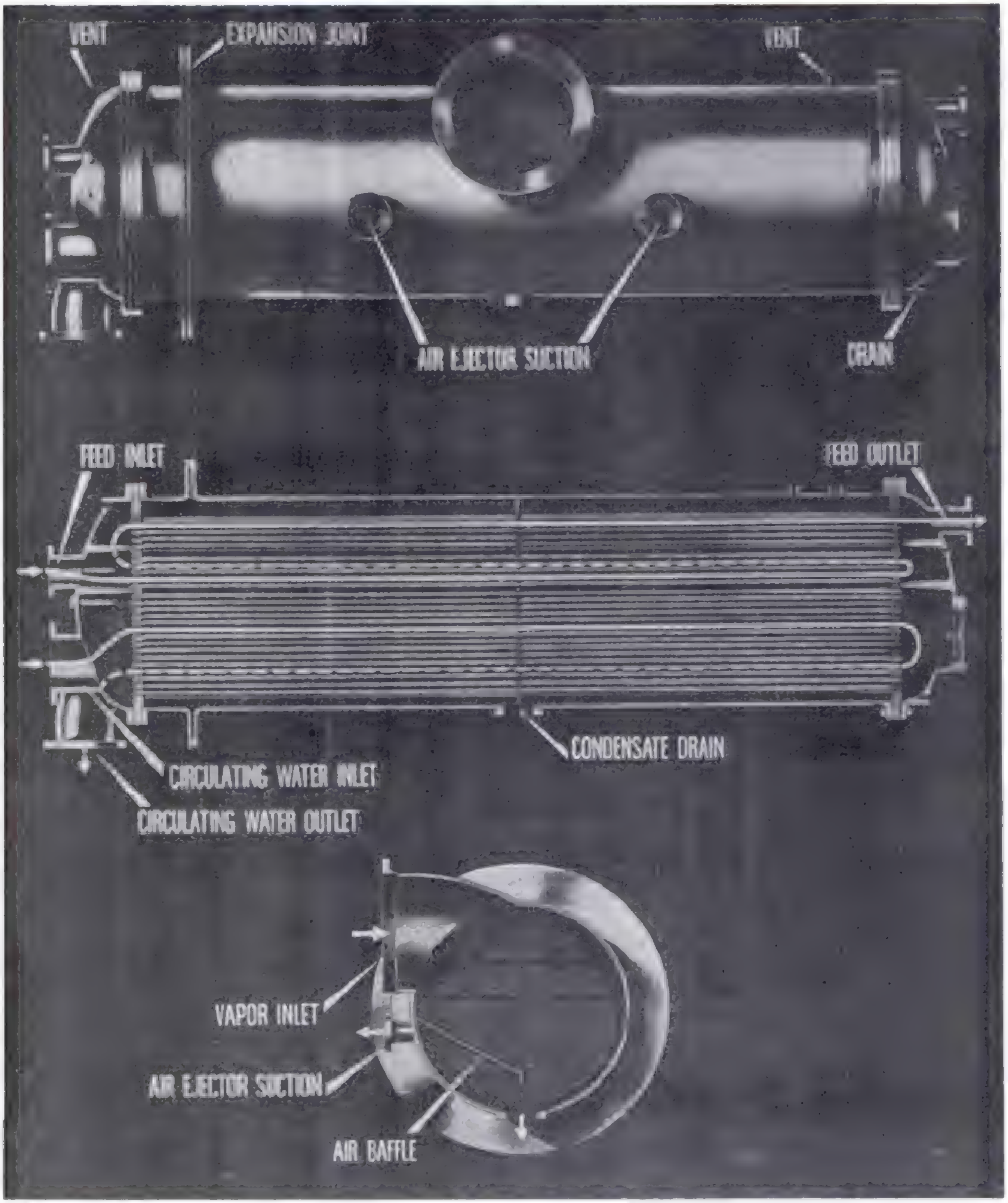
The weir proper is carried on an adjusting screw which permits the height to be adjusted to any desired operating level. The bottom of the weir chamber is water-sealed to prevent equalizing shell pressures.

The level controllers consist of a chamber in parallel with the evaporator shell. A weir pipe within each evaporator shell discharges into a weir well. Feed water in excess of that which is evaporated spills over the weir pipe and into the weir well.

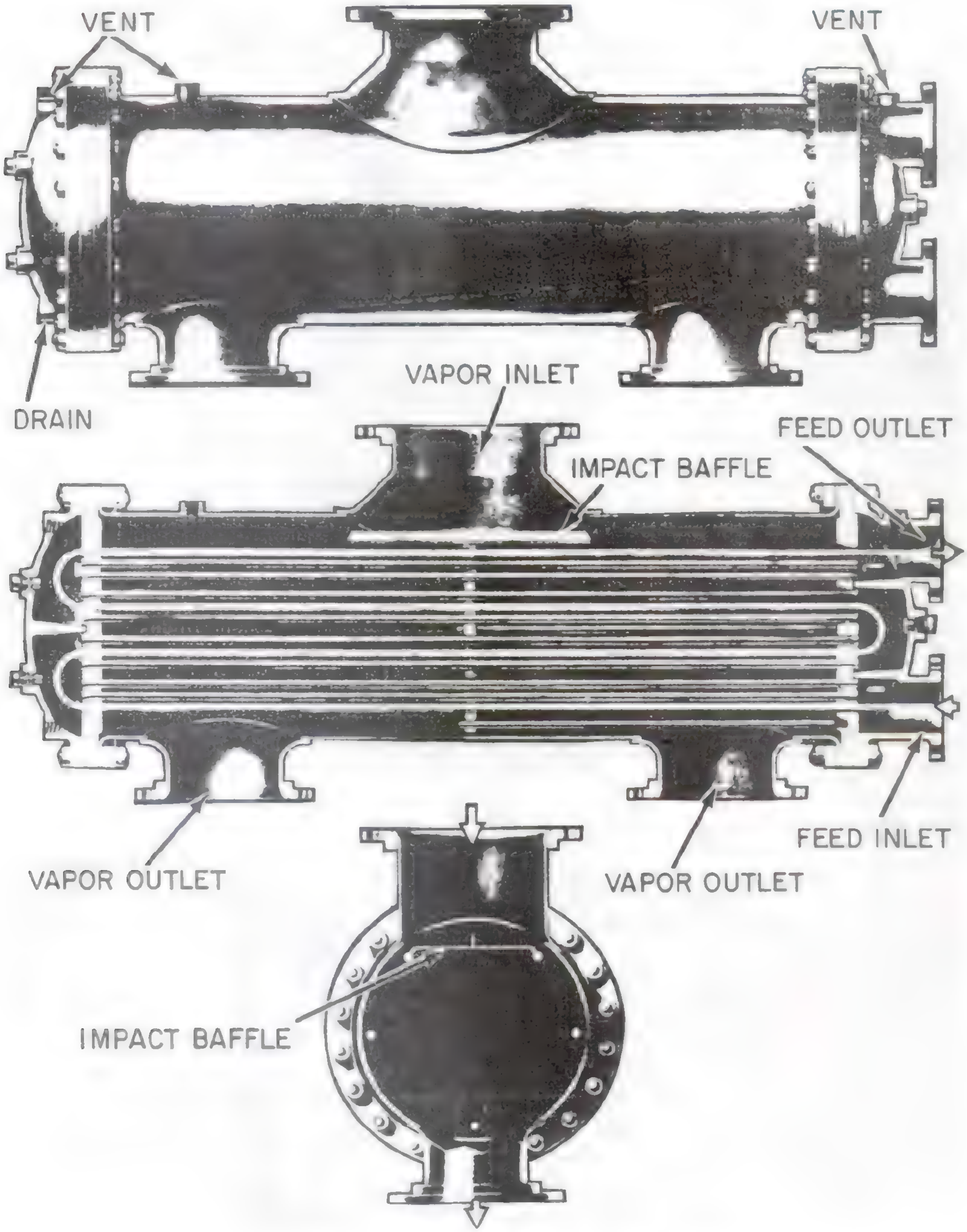
The internal weir pipe may be raised or lowered by the external handwheel. The weir well vents into the weir chamber by a pipe which also serves as a guide for the weir pipe. A gage glass is installed on the weir well.

Flowrator

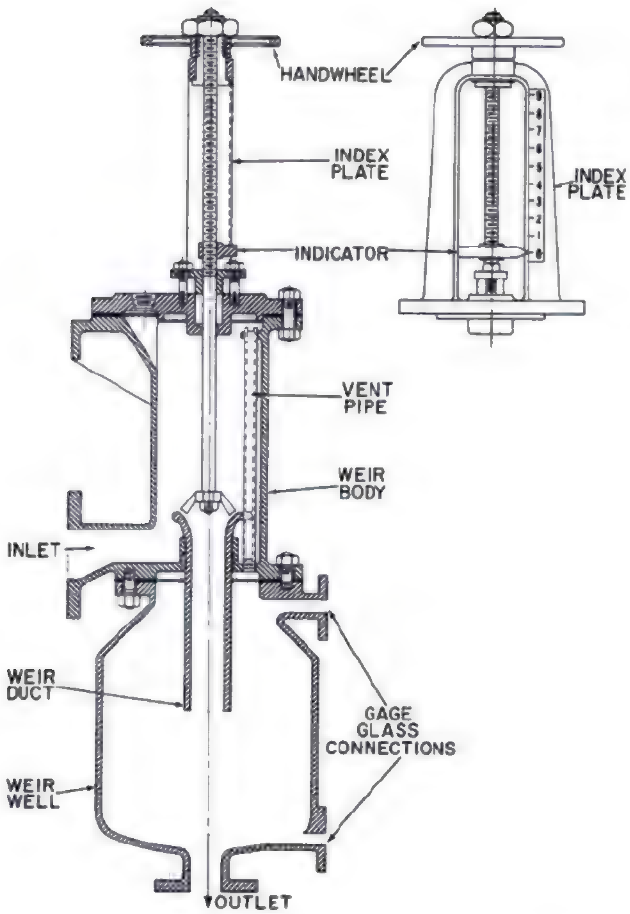
A few distilling plants may be equipped with a flowrator (rotameter) or some other visual flow indicator in the evaporator feed line. Flowrators are calibrated in gallons per minute (gpm) and it is possible to set the rate-of-feed by adjusting a hand valve in the feed line. In order to maintain the proper density (1.5/32) in



47.119
Figure 13-5.—Distilling condenser.



47.120
Figure 13-6.—Vapor feed heater.



47.121
Figure 13-7.—Weir type level controller.

the last-effect shell, 3 gallons of sea water feed must be fed into the distilling plant for each gallon of distilled water produced. The remaining 2 gallons of concentrated sea water (brine) are pumped overboard. The flowrator measures the amount of incoming feed water against the amount of distillate being produced. A check of the brine density leaving the last effect shell should also be used to assure that the feed water flow is correct.

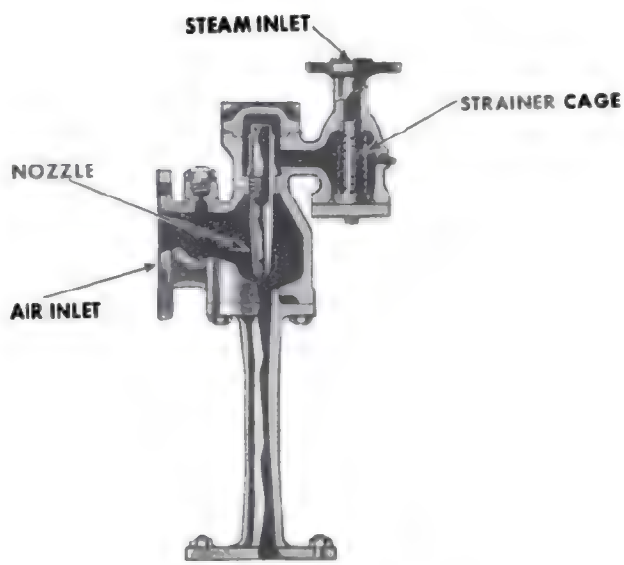
Solenoid-Operated Distillate Bypass Valve

In later installations, a three-way solenoid trip valve is usually provided to divert the output to the bilge whenever the purity is unsatisfactory. The solenoid valve is tripped automatically whenever the salt content at the distillate cooler outlet exceeds 0.25 grains per gallon (gpg) or 0.065 equivalent parts per million (epm). When this occurs, the distillate continues to flow to the bilge and an alarm is sounded on the conductivity meter panel.

The solenoid valve is so wired that flow can be directed to the ship's tanks only when the solenoid is energized. An increase in salinity to more than 0.25 gpg (0.065 epm) deenergizes the solenoid and trips the valve to the bilge. This arrangement makes it impossible to reset the valve to discharge to the ship's tanks until the salinity is below 0.25 gpg (0.065 epm) and the solenoid is again energized. In the event of a power failure at the panel, the solenoid valve will trip and discharge to the bilge.

Air Ejector

The function of air ejectors is to remove the noncondensable gases, mainly air, which may leak or be discharged into condensers operating under a vacuum. The air ejector (fig. 13-8) is a comparatively simple mechanism consisting of a steam inlet and nozzle, an inlet for the saturated air from the condenser, and a diffuser tube. Steam (125 to 150 pounds) is led to the air ejector and passes through the nozzle. The steam attains a high velocity as it passes from the nozzle. The high-velocity steam jet issuing



47.122
Figure 13-8.—Air ejector.

from the nozzle creates a suction and draws in the saturated air from the distilling condenser. Two air ejectors are usually provided for each distilling plant; however, one unit is usually sufficient to operate the plant.

Air Ejector Condenser

The steam-air mixture discharged from the air ejector is normally condensed in a shell and tube type air ejector condenser (fig. 13-9). This is nothing more than a bank of tubes divided by a series of baffles and enclosed in a shell. The baffles ensure that the steam-air mixture passes over the entire cooling surface of the tubes before reaching the air vent. The steam is condensed and the resulting condensate is led into the low pressure drain system.

Distillate Cooler

The distillate cooler (fig. 13-10) is a tubular surface multipass heat exchanger. The fresh water (distillate) from the distilling condenser is drawn out by the distillate pump and discharged through the tubes of the distillate cooler. (Later units circulate the sea water through the tubes and the distillate around the tubes.) From here the distillate is further drawn out by the fresh water pump. (Later units omit the fresh water pump.)

Flash Chamber

The flash chamber is essentially a receptacle within which the second-effect drains are reduced to a pressure and temperature corresponding to the distilling condenser vacuum. The flash chamber is attached or located on the third-effect side of the evaporator shell.

Tube-Nest Drain Regulator

A tube-nest drain regulator (fig. 3-11) is installed in the drain line from each evaporator tube nest. The drain regulator consists of a body and cover enclosing a balanced cage or rotary valve operated by a ball float. The drain regulator prevents the generating steam from blowing through the tube bundle in the first, second, and third effects.

Pumps

Distilling plant pumps are constant speed, centrifugal, motor driven type. No details on operation, construction, or maintenance are given here; information on centrifugal pumps may be found in chapters 5 and 6 of this training manual. Distilling plant pumps should always be installed with a submergence equal to that specified on the nameplate or given by the manufacturer. The pump's speed and direction of rotation should be checked frequently and rechecked after any work is done on the pump or motor. For detailed information on any given unit, consult the Shipboard Planned Maintenance System (3-M) or manufacturer's technical manual.

VERTICAL BASKET DISTILLING PLANTS

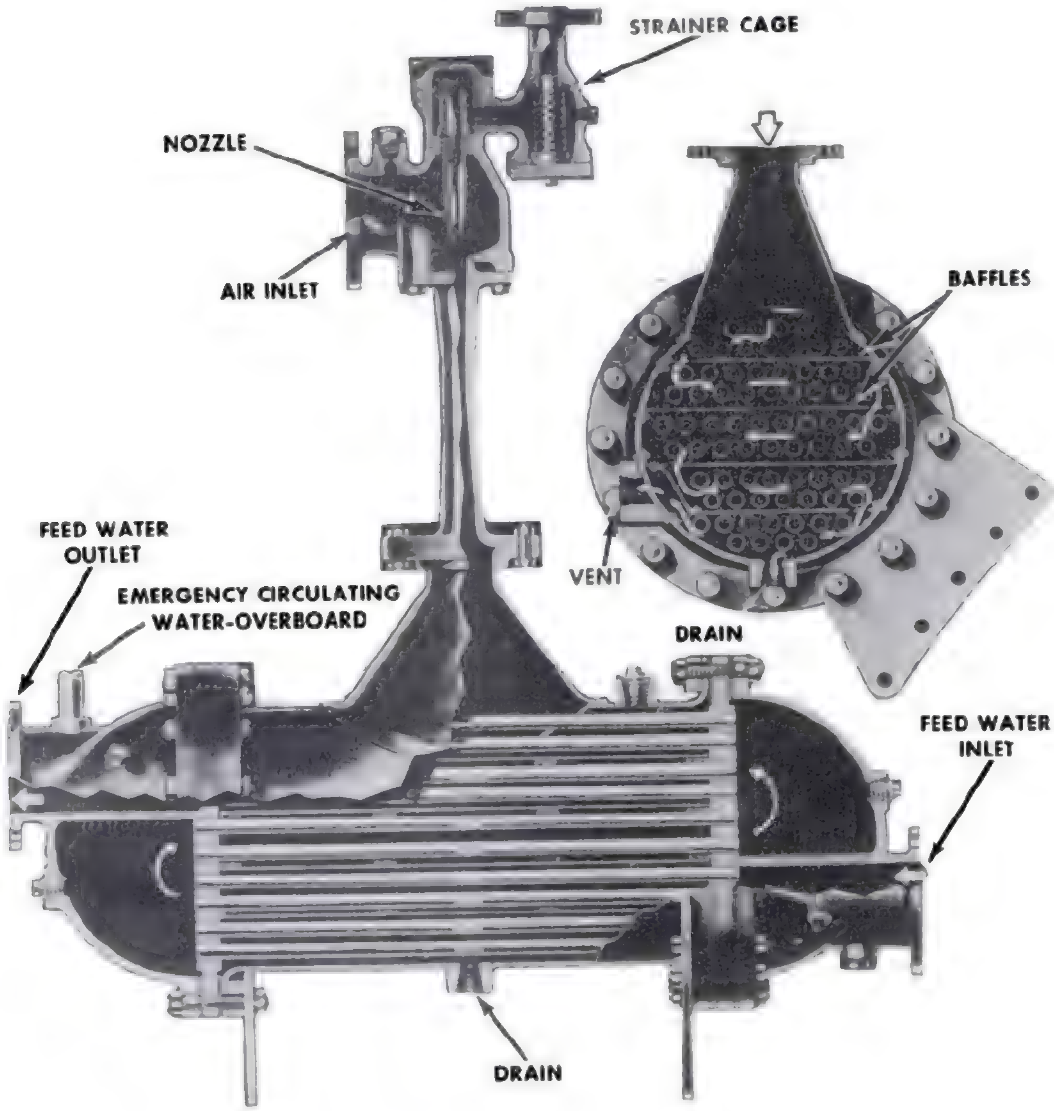
Most modern ships are being equipped with distilling plants that differ somewhat from the submerged tube type. One such type is the vertical basket plant.

The low pressure vertical-basket type distilling plant (fig. 13-12) consists of two-effect (or more) evaporators with a distiller condenser, vapor feed heaters, air ejectors and after condensers, and a distillate cooler. The only difference between this type of distilling plant and the conventional submerged-tube type is in the evaporators. Each evaporator consists of a vertical shell into which a deeply corrugated vertical basket is installed. See fig. 13-13. In some installations more than one basket may be installed. Low pressure steam is admitted to the inside of the first-effect basket and feed water is boiled in the space between the outside of the basket and the shell. The vapor formed from the boiling feed water passes through centrifugal-type vapor separators and the vapor feed heater into the inside of the second-effect basket. This boils the brine from the first-effect in addition to a certain amount of feed water in the space between the shell and the basket. The vapor thus formed passes through separators to the subsequent effects, or in a two-effect basket, into the distiller condenser.

The flow circuits of a vertical basket distilling unit are illustrated schematically in figures 13-14, 13-15, and 13-16. Refer to these figures as you study the following descriptions of the flow circuits of the unit.

STEAM FLOW CIRCUIT

Heating steam from the ship's auxiliary exhaust main is fed through a pressure-control valve to the steam chest of the first effect.



47.123
Figure 13-9.—Air ejector condenser.

The pressure-control valve is set to maintain a constant steam-supply pressure; it should be set for 5 psig steam on the upstream side of the orifice plate for rated output, and lower for reduced output. The heating steam is condensed within the corrugated basket; the condensate is returned to the ship's condensate system or reserve feed tanks by the first-effect drain pump. (See fig. 13-14.)

A steady water level is maintained in the suction line of the first-effect drain pump by the drain controller; this ensures a positive submergence head for the pump. If the first-effect drain pump fails, the evaporator can be kept in operation by bypassing the drain controller and manually controlling the condensate discharge to the low pressure drain mains; at least 1 psig pressure in the steam chest is

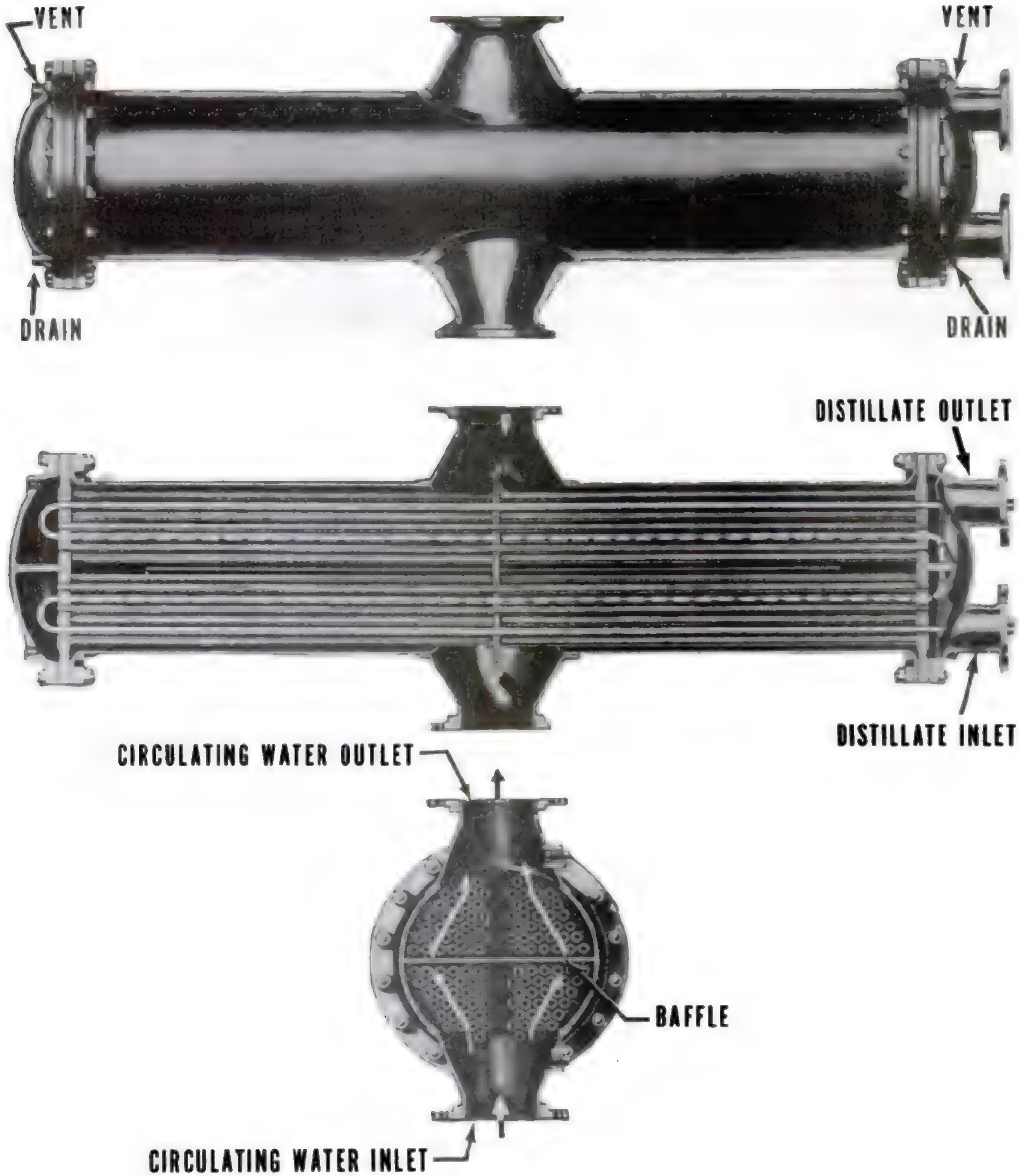


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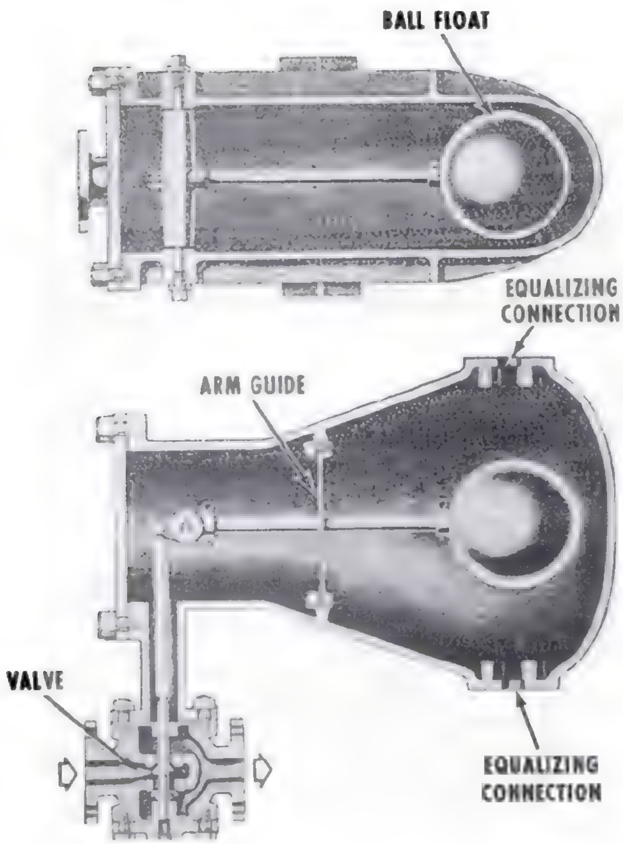
Figure 13-10.—Distillate cooler.



47.125
Figure 13-11.—Tube-nest drain regulator.

required, under these conditions, to drain the condensate.

FEED FLOW CIRCUIT

Sea water feed is taken from a sea chest, through a strainer, by the sea water circulating pump, and is discharged, through the distillate cooler. (The incoming feed serves to cool the distillate from the distiller condenser to within a few degrees of the temperature of the feed.) The sea water then passes through the distiller condenser; the major portion (about 75%) goes through the eductor, combines with the brine (from the second effect), and is discharged overboard. (See fig. 13-16.)

The feed remaining in the condenser is directed through the after condenser and the vapor feed water heater to the first effect, where it surrounds the basket. Violent boiling takes place and vapor forms within the first effect. The remaining brine serves as feed for the second effect.

The brine from the second effect is removed by the brine overboard-discharge pump; it is discharged overboard, through the eductor and control valve, after it has been combined (in the eductor) with the sea water overboard discharge from the distiller condenser (figs. 13-14 and 13-15).

VAPOR CIRCUIT

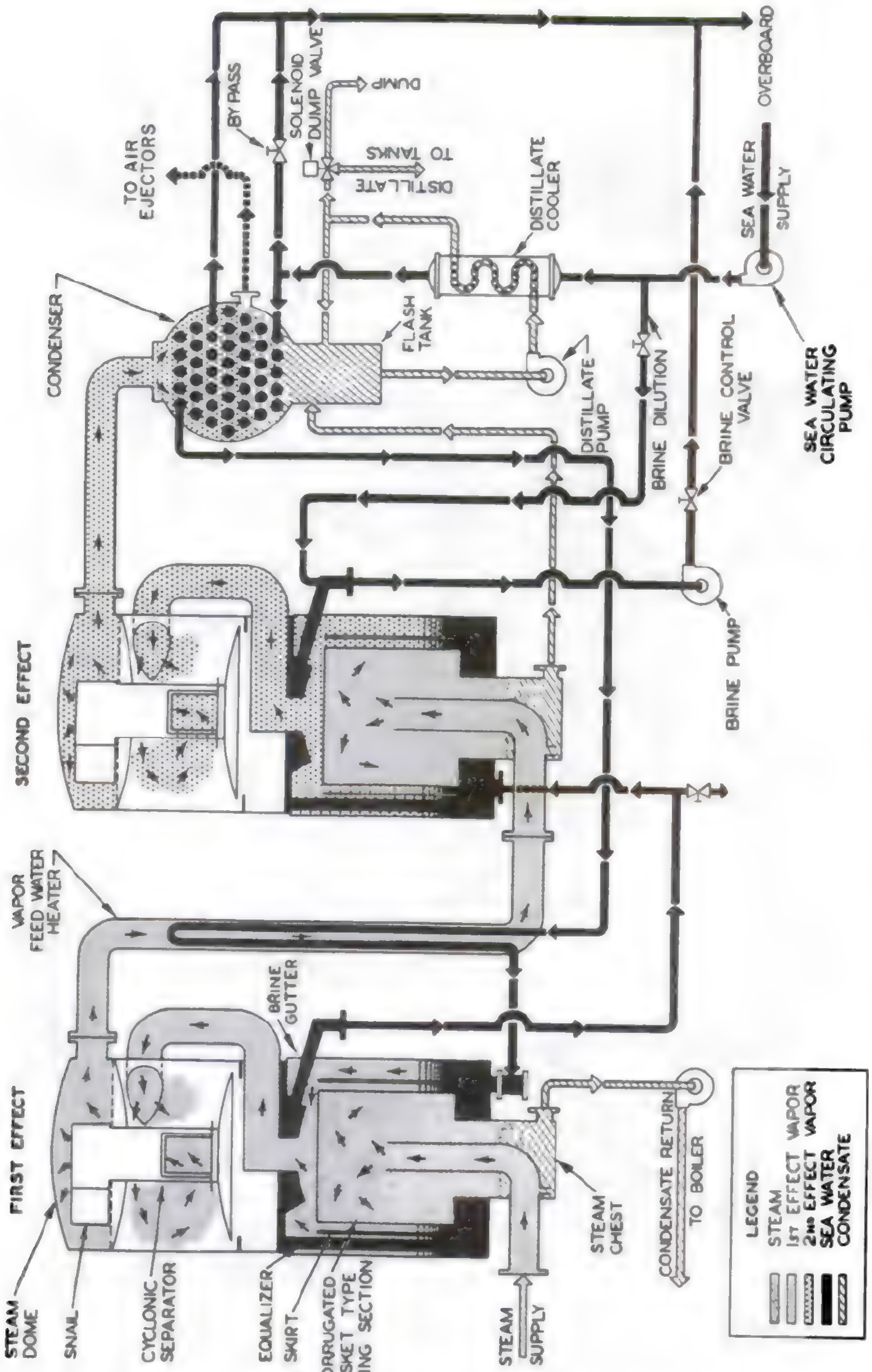
The vapor which forms as a result of the boiling of the feed in the first effect passes through the uptake pipe and enters the cyclonic separator above the evaporation section. Most liquid particles which carry over with the vapor are removed by centrifugal force within the first-effect separator. The first-effect vapor passes from the steam dome, through the vapor feed water heater, to the steam chest and the evaporator basket of the second effect. Some of the vapor, in passing from the first effect to the second effect, condenses as it heats the feed water passing through the vapor feed water heater. The major portion of the first-effect vapor, however, enters the second-effect steam chest and condenses as it heats the brine in the second effect (figs. 13-14 and 13-15).

The vapor resulting from the boiling of the brine in the second effect passes through the second-effect uptake into the second-effect separator, where centrifugal force is utilized to remove water particles from the second-effect vapor. (Liquid particles from both stages drain downward and become part of the brine drains.) This two-stage separation results in distillate with less than 0.065 epm chloride, under normal operating conditions. From the second-stage separator, the vapor passes, through the steam dome, to the distiller condenser, where the vapor is condensed as it is cooled by the incoming feed. (See figs. 13-15 and 13-16).

DISTILLATE CIRCUIT

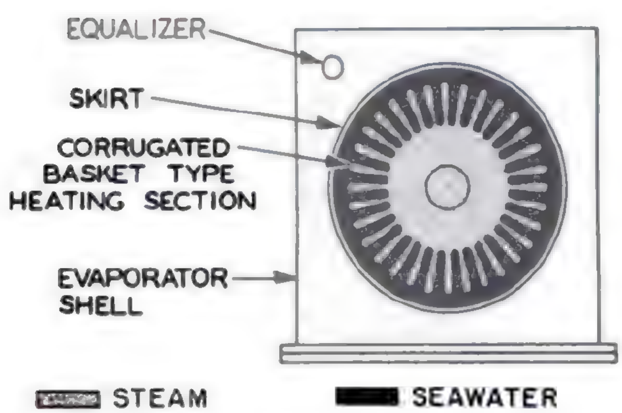
The condensate formed in the second-effect steam chest passes, through a loop seal, to the flash tank of the distiller condenser, under the pressure differential existing between the second-effect steam chest and the flash tank. The loop seal permits only condensate to pass.

The vapor from the second-effect steam dome condenses in the distiller condenser and

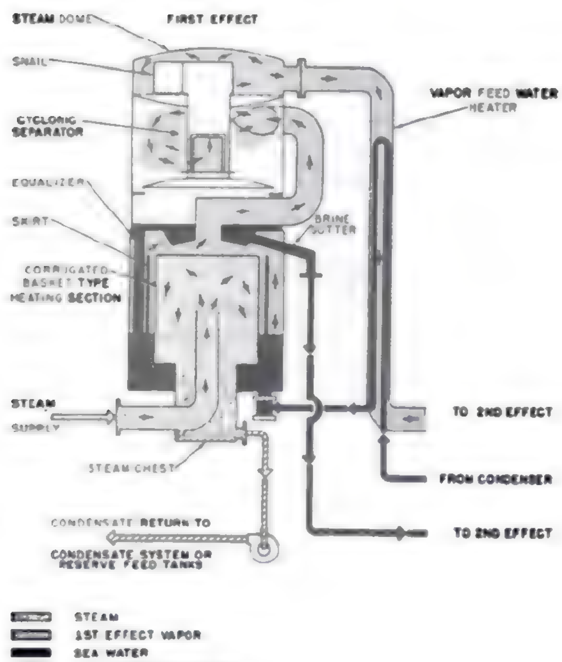


47.126

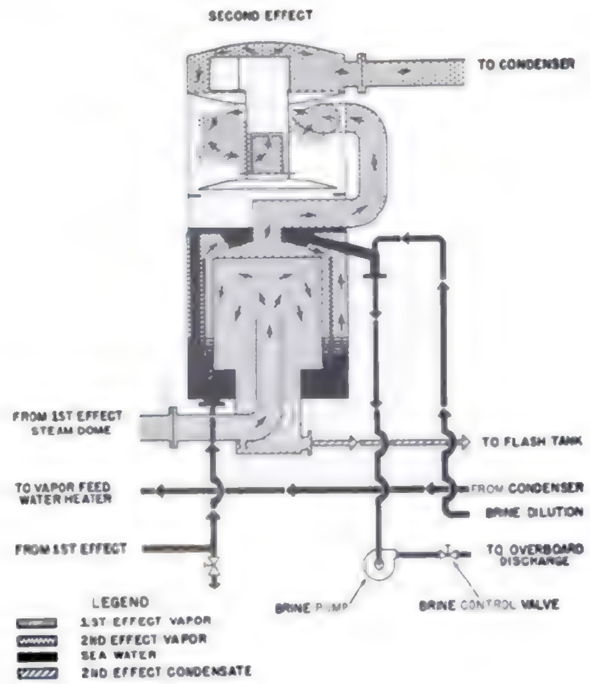
Figure 13-12. — Low pressure double-effect distilling plant (vertical basket type).



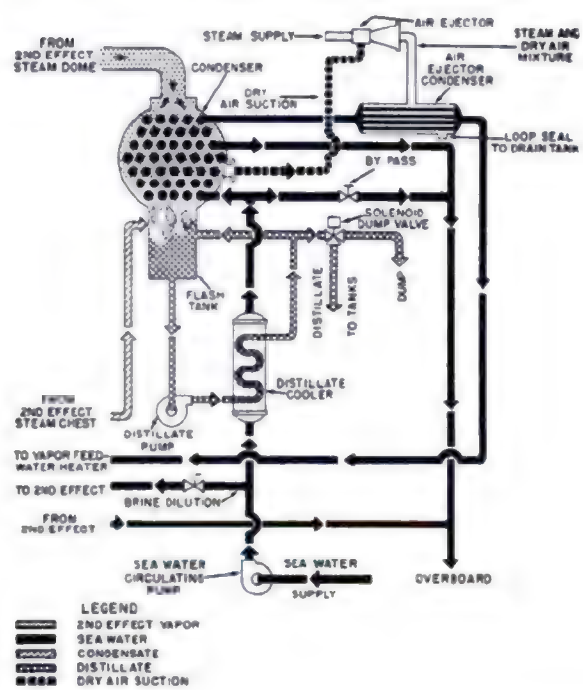
47.127
Figure 13-13.—Section view of evaporator (vertical basket type).



47.128
Figure 13-14.—Flow circuits of a vertical basket unit-first-effect section.



47.129
Figure 13-15.—Flow circuits of a vertical basket unit-second-effect section.



47.130
Figure 13-16.—Flow circuits of a vertical basket unit-condenser section.

collects in the flash tank at the bottom of the distiller condenser. The distillate (combined condensate drains from the distiller condenser and the second-effect steam chest) is removed from the flash tank by the distillate pump and is discharged, through the distillate cooler and the solenoid-operated dump valve, to the ship's service tanks (figs. 13-15 and 13-16).

In some vertical basket units, the discharge rate of the distillate pump is controlled automatically by a drain controller. The drain controller maintains a positive water level in the flash tank so that the pump will not become vapor bound. Later models of vertical basket units have been equipped with a recirculating line (fig. 13-16) to the flash tank, instead of a drain controller. A throttle valve is included in the recirculating line. The recirculating line supplies relatively cold fresh water to the flash tank. The cooling water reduces the temperature of the distillate below the flash point; thus vapor lock within the distillate pump is prevented. The recirculating line also ensures, through control of the throttle valve, a positive suction head on the distillate pump.

Under normal operating conditions, the vertical basket distilling unit produces distillate with less than 0.065 epm chloride (0.25 grains salt per gallon). If the unit is to produce relatively pure distillate, it is essential that salt water be prevented from entering the vapor and condensate systems. To prevent salt water contamination of the ship's fresh water supply, a salinity cell is provided in each of the unit's fresh water lines. If a salt water leak should develop in the distillate circuit, the salinity indicator actuates the solenoid dump valve, which diverts the contaminated water to the bilge until the unit can be secured and the leakage stopped.

NONCONDENSABLE GASES

Air and other noncondensable vapors in the distiller condenser are removed and vacuum is maintained throughout the evaporator units by an air ejector. The ejector is of the single-nozzle, single-stage, steam jet type. The ejector is mounted on the side of the distiller condenser, and takes its suction from a specially baffled section within the distiller condenser. Vent lines and interconnecting vapor-piping connect components in which vacuum must be maintained.

The air ejector removes the air and other noncondensable vapors from the distiller condenser by utilizing the energy in steam at 150 psi. The gages entering the suction of the ejector are entrained by the steam jet from the nozzle and are carried through the diffuser, where the pressure is raised to that of the atmosphere. The ejector discharges into a surface after-condenser, where the steam is condensed and the noncondensable gases are vented to the atmosphere.

FLASH TYPE DISTILLING PLANTS

Some of the later ships are being equipped with flash type distilling plants. These plants use low pressure steam and operate on the principle of evaporation followed by condensation. The flash type unit may have two or more stages. For example, CVA-62 is equipped with five-stage units, each having a capacity of 50,000 gallons per day. Two-stage units of 12,000 gallons per day are being installed on new destroyer type ships.

PRINCIPLES OF OPERATION

Each stage of a flash unit has a flash chamber, a feed box, a vapor separator, and a distilling condenser. There is also a two- or three-stage air ejector, a distillate cooler, and a feed water heater. Feed water passes through the tubes of the distillate cooler, the stage distilling condensers, and the air ejector condenser. In each of these heat exchangers the feed water picks up heat and the final heating is done by low pressure steam admitted to the shell of the feed water heater. From this heater the feed water enters the first-stage feed box and comes out through orifices into the flash chamber. As the heated feed water enters the chamber, a portion flashes or vaporizes because the pressure in the chamber is lower than the saturation pressure corresponding to the temperature of the hot feed. This vapor condenses on the tubes of the first-stage distilling condenser. The feed which does not vaporize in the first chamber passes to the second chamber. The process is repeated in each stage and the brine remaining in the last stage is removed by the brine overboard pump. Vapor formed in each stage passes through a vapor separator and into the stage condenser where it is condensed

to distillate. The distillate passes through a loop seal on its way to the distilling condenser of the next stage. The distillate pump removes the distillate from the last stage.

BASIC PARTS OF A TWO-STAGE FLASH UNIT

The basic component of the unit is the distiller shell. The shell is divided to form the two stages (flash or vacuum chambers) of the unit. Most accessories for the unit are mounted directly on the shell. The piping system of the unit includes the essential pumps and strainers and an electrical salinity-indicator system. The relative location of these components and the flow circuits of the unit are shown in the diagrammatic arrangement of the unit, figure 13-17. Refer to that figure and trace the various circuits; become familiar with the relative location of the components as you study the following description of the distilling unit.

Distiller Shell and Internal Parts

The distiller shell contains the two flash (vacuum) chambers; each flash chamber contains a feed-inlet box, a vapor separator, and a distiller condenser.

The first- and second-stage FLASH CHAMBERS are separated from each other by a vertical wall through the center of the distiller shell. In each chamber, the vapor separator and the distilling condenser are located at the top and the feed-inlet box is located at the bottom.

Access openings to each flash chamber are provided through the front of the distiller shell. Sight glasses are provided on the side of each flash chamber for observing the conditions within the flash chamber during operation. Gage glasses mounted on the access covers indicate the level of the water within each flash chamber. A screen is fitted over the suction connection to the brine-overboard pump to prevent scale, which may form on and flake off the distiller shell, from passing into the brine pump.

Hot feed enters the distiller shell through the FEED-INLET BOXES. The construction of a feed-inlet box is illustrated in figure 13-18.

A series of orifice plates is bolted to the bottom of the box. A spreading plate is located directly above the orifices.

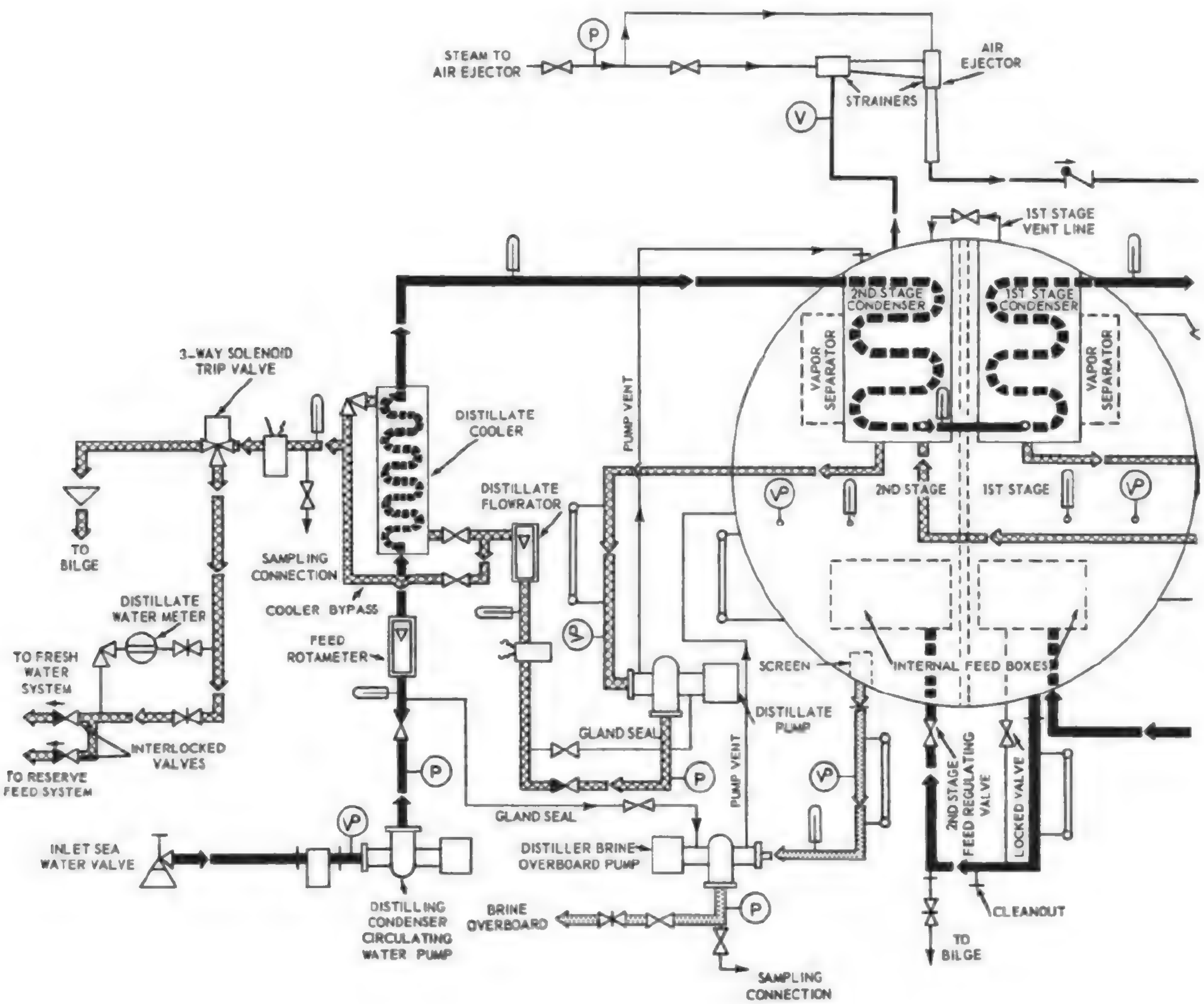
Vapor which flashes from the hot feed introduced from the feed boxes flows to the VAPOR SEPARATORS. Each vapor separator is mounted in an opening in the plate which separates the distiller condenser from the flash chamber. Two types of vapor separators are used. In one, a separator consists of several rows of vertical hooked vanes. These vanes are arranged to change the direction of flow of the vapor several times, and to trap and remove all entrained moisture. The other type of vapor separator (or demister) consists of a stack of numerous piles of woven wire cloth mesh on which the water droplets collect or form, and drain back into the flash chamber. The vapor flows through the demister into the condenser.

The flash vapor from each stage is condensed on the shell side of the DISTILLER CONDENSER in each flash chamber. The salt water feed flowing through the tubes of the condenser is heated as it absorbs the heat given off by the vapor as it condenses. The distillate collects in the bottom of the condenser.

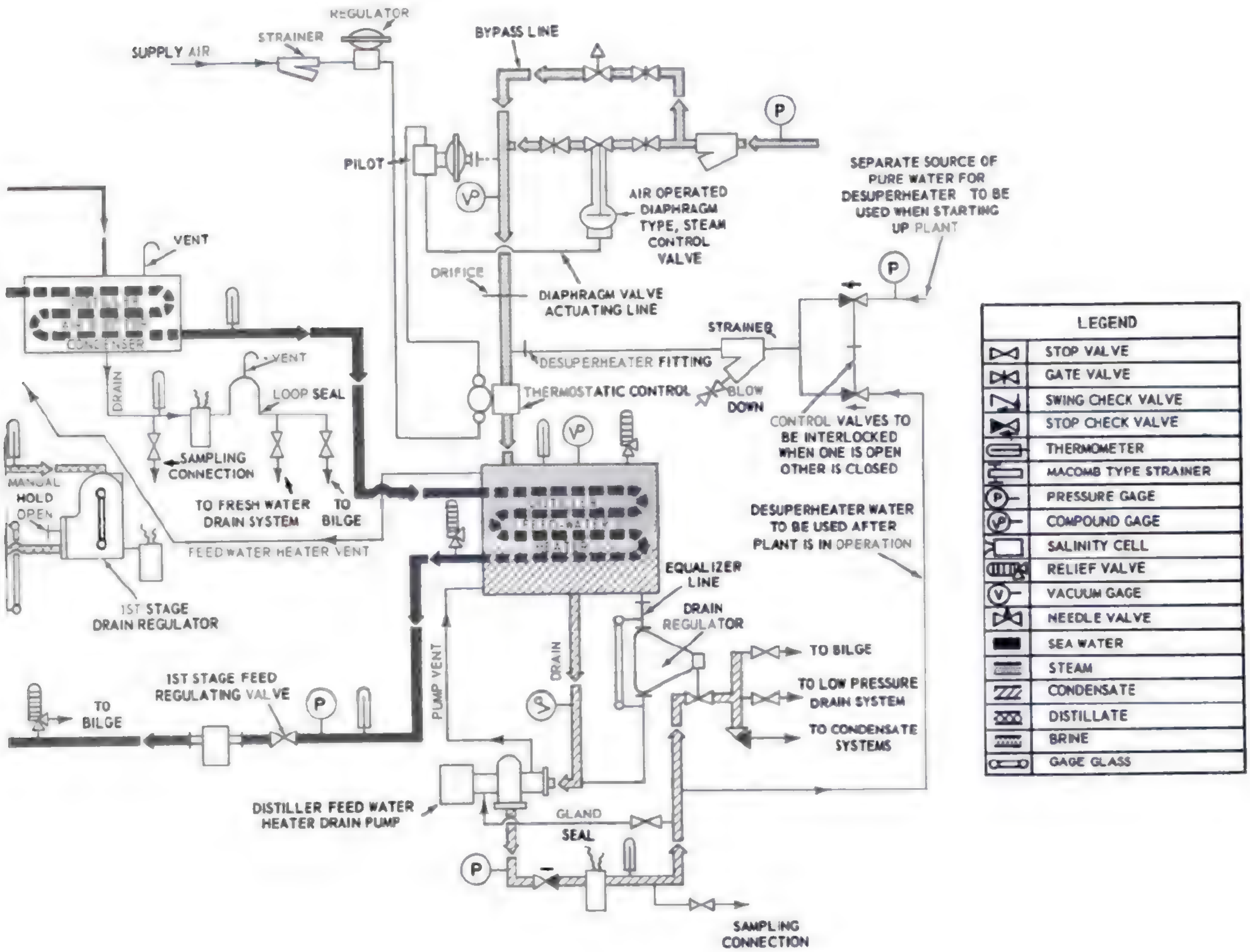
The distiller condensers are of the straight-tube or U-tube type; the tubes are roller-expanded into the tube sheets. A removable head provides access to the inside of the tubes. Each head is designed to direct the flow of the water through the tubes in several passes. The heads are fitted with vents and drains. A plate welded to the shell provides support at the middle of the tube bundle. A diaphragm-type expansion joint between the rear shell head and the rear tube sheet allows for differential expansion of the tubes when straight tubes are used. Several baffles are arranged within the shell to direct the flow of the vapor through the shell from the warmest pass to the coolest pass. A separate baffle around the vent connection on each condenser forms an air cooling section; in this section the air and other noncondensable gases are forced to travel across a portion of the coolest pass of the condenser before they are released. This arrangement reduces the volume of gas going to the air ejector and the vapor loss through the air ejector.

Accessories

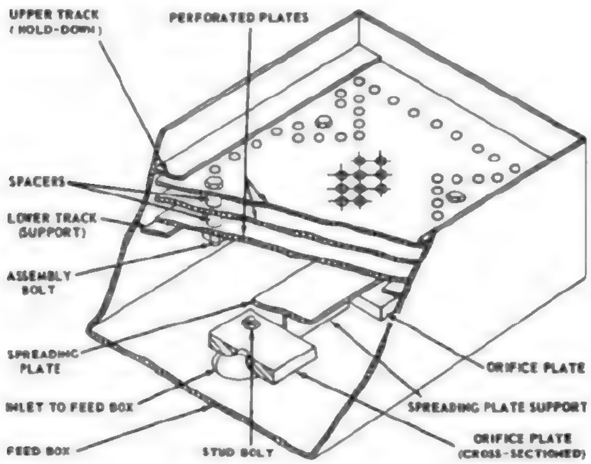
The accessories for the two-stage unit include heat exchangers, drain regulators, flow indicators, an air ejector, a dump valve, and numerous thermometers, pressure gages, and fittings. Many of these accessories are similar in design to and operate on the same principles



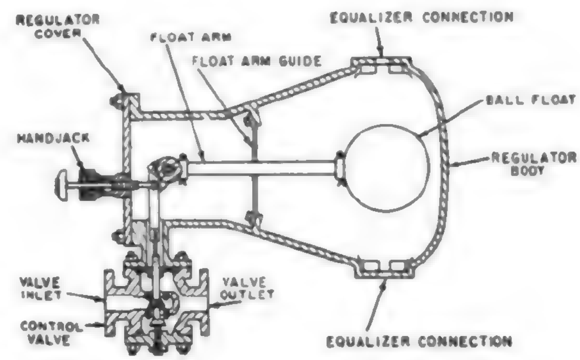
STEAM TO AIR EJECTOR
P
AIR EJECTOR
STRAINERS
V
1ST STAGE VENT LINE
2ND STAGE CONDENSER
1ST STAGE CONDENSER
VAPOR SEPARATOR
VAPOR SEPARATOR
3-WAY SOLENOID TRIP VALVE
DISTILLATE COOLER
PUMP VENT
TO BILGE
DISTILLATE FLOWRATOR
2ND STAGE
1ST STAGE
VP
SAMPLING CONNECTION
COOLER BYPASS
DISTILLATE WATER METER
FEED ROTAMETER
TO FRESH WATER SYSTEM
SCREEN
INTERNAL FEED BOXES
DISTILLATE PUMP
INTERLOCKED VALVES
GLAND SEAL
TO RESERVE FEED SYSTEM
PUMP VENT
2ND STAGE FEED REGULATING VALVE
LOCKED VALVE
GLAND SEAL
INLET SEA WATER VALVE
DISTILLER BRINE OVERBOARD PUMP
CLEANOUT
DISTILLING CONDENSER CIRCULATING WATER PUMP
BRINE OVERBOARD
TO BILGE
SAMPLING CONNECTION



47.131
Figure 13-17.—Diagrammatic arrangement of a two-stage flash unit (Griscom-Russell).



47.132
Figure 13-18.—Feed-inlet box.



47.133
Figure 13-19.—Evaporator feed water heater drain regulator.

as comparable accessories used in connection with the submerged-tube distilling unit.

In addition to the distilling condensers, the distilling unit requires a feed water heater, an air ejector condenser, and a distillate cooler. These HEAT EXCHANGERS are of the same basic design; they differ principally in size, and number of tubes.

The required level in the suction line between the feed water heater and its drain pump is maintained by the EVAPORATOR FEED WATER HEATER DRAIN REGULATOR. This regulator is of the ball-float external-valve type. The construction of the regulator is shown in figure 13-19.

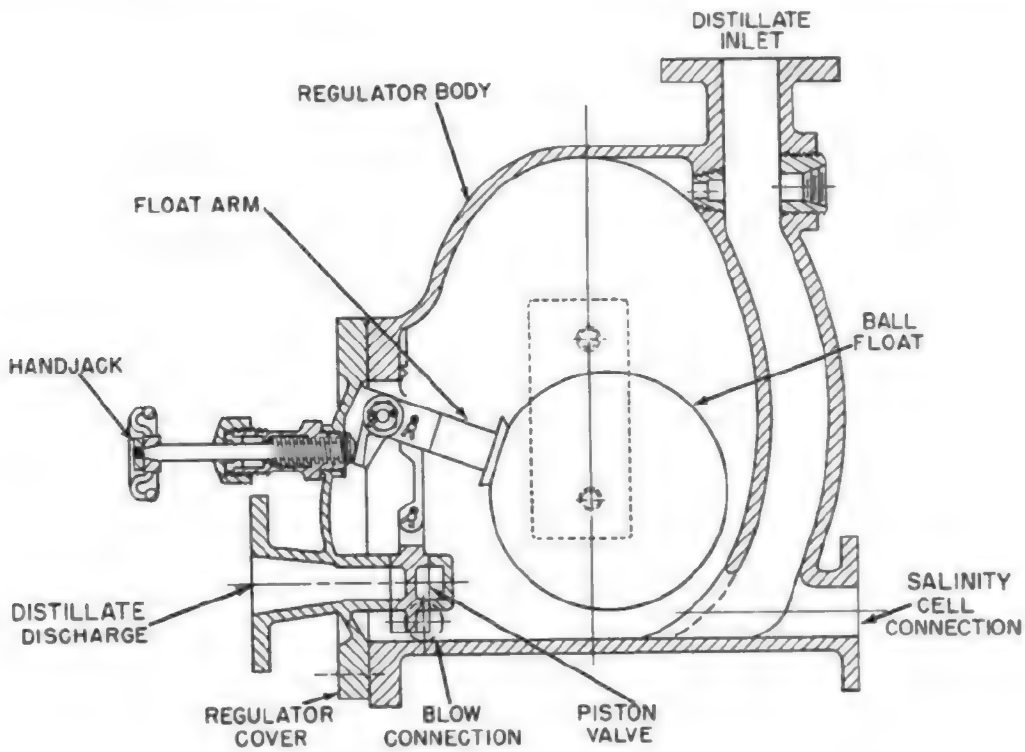
The body of the drain regulator is connected in parallel with the suction line to the feed water heater drain pump. The regulator maintains a level in the suction line by throttling on the drain-pump discharge which passes through the external control valve on the drain regulator. A handjack on the regulator cover can be used to manually hold the valve open. A gage glass is provided on the regulator body to show the level being held in both the body and in the suction line to the feed water heater drain pump.

The flow of distillate from the first-stage distilling condenser to the second-stage distilling condenser is controlled via a loop seal or by an orifice or by the FIRST-STAGE DISTILLATE DRAIN REGULATOR. This regulator is of the ball-float internal-valve type. The construction of the regulator is shown in figure 13-20.

The distillate from the bottom of the first-stage distilling condenser enters the top of the drain regulator, passes through the body, and is discharged through the piston-type valve into the bottom of the second-stage distilling condenser. A gage glass is provided on the regulator body to indicate the level within the body. A handjack on the regulator cover can be used to hold the valve open manually. The regulator is self-venting.

The salinity of the distillate at various points within the distillate circuit is indicated by an electrical SALINITY INDICATING SYSTEM. The system includes five cells. One cell is installed in each of the following locations: distillate outlet from the distillate cooler; distillate inlet to the distillate cooler; distillate drains from the first-stage distilling condenser feed; water heater drain pump discharge; and air ejector condenser drain line (fig. 13-18). An alarm sounds whenever the salinity at any cell exceeds 0.065 epm. All cells register on the salinity indicating panel. The arrangement is such that when the salinity of the distillate exceeds 0.065 epm the cell in the outlet of the distillate cooler causes the solenoid of the THREE-WAY TRIP VALVE to be de-energized. This causes the valve to trip, and the contaminated distillate is discharged to the bilge. Once the valve has been tripped, the distillate will continue to flow to the bilge until the valve is reset manually.

The distilling unit is provided with VENTS at numerous points (see fig. 13-18). The feed water heater shell is vented, through a line with a control valve, to the shell of the first-stage distilling condenser. The first-stage



47.134
Figure 13-20.—First-stage distillate drain regulator.

distilling condenser is vented, through a line with a control valve to the second-stage condenser. The second-stage condenser is vented to the atmosphere through the air ejector and air ejector condenser.

The feed water heater drain pump is vented to the feed water heater shell. The brine-overboard pump is vented to the second-stage flash chamber. The distillate pump is vented to the second-stage condenser.

CIRCUITS OF A TWO-STAGE FLASH UNIT

While flash units differ from submerged tube units in design, the same types of circuits are found in both types of units. The circuits of the flash unit are described here under the headings of steam, feed, and vapor and distillate circuits, and the air ejector systems.

Steam Circuit

The heat required for the distillation process is provided by steam from the auxiliary exhaust main. The steam is supplied to the evaporator feed water heater. (See fig. 13-17.)

The steam pressure is reduced from 15 pounds to 5 pounds by an air-operated diaphragm-type STEAM REGULATING VALVE. This valve is operated from a 20 psi air supply line, and maintains 5 pounds of steam pressure ahead of the ORIFICE in the steam line. After passing through the orifice, the steam is desuperheated by a DESUPERHEATER NOZZLE in the steam line. The steam then enters the shell of the EVAPORATOR FEED WATER HEATER and condenses outside of the tubes. The condensate is removed from the heater by the evaporator feed water heater drain pump and is discharged through a salinity cell and a drain regulator to the bilge, to the steam-drain collecting system, or to the ship's condensate system.

Desuperheating water may be furnished from the evaporator feed water heater drain pump when the distilling unit is in operation; however, the water must be supplied from the ship's condensate system when the unit is being started.

Feed Circuit

THE DISTILLING CONDENSER CIRCULATING WATER PUMP takes feed, through a strainer, from a sea chest. The evaporator feed water is discharged through the FEED ROTAMETER and through the tubes of the DISTILLATE COOLER in a single pass. From the distillate cooler, the feed flows through the tubes of the SECOND-STAGE DISTILLING CONDENSER where the feed condenses the vapor released in the second stage. The feed then passes through the tubes of the FIRST-STAGE DISTILLING CONDENSER where it performs a similar function. (The evaporator feed water is heated as it passes through the distilling condensers by absorbing the latent heat of condensation. This reduces the amount of heat to be absorbed in the evaporator feed water heater.) From the first-stage distilling condenser, the feed flows through the distillate AIR EJECTOR CONDENSER where a little more heat is absorbed; it then flows into the EVAPORATOR FEED WATER HEATER. The final heating of the feed is accomplished as the feed passes through the tubes of the heater. The heated feed passes through the FIRST-STAGE FEED REGULATING VALVE and a Macomb-type strainer into the FIRST-STAGE FEED BOX.

Since the pressure in the first-stage flash chamber is lower than the saturation pressure corresponding to the temperature of the evaporator feed water, the water will flash to the lower pressure and thus release vapor. Most of the flashing takes place as the water emerges from the orifices in the feed box.

The feed which does not vaporize in the first stage flows out through an external loop seal and into the SECOND-STAGE FEED BOX. (The pressure differential between the two stages causes the feed to flow through the loop seal.) Since the second stage is at a lower pressure (higher vacuum) than the first stage, an additional portion of the feed vaporizes in the second-stage flash chamber. The brine remaining in the second stage after flashing occurs flows out of the distiller shell, through a strainer, and is discharged overboard by the BRINE-OVERBOARD PUMP.

Vapor and Distillate Circuits

The vapor flashed from the evaporator feed water in the first-stage flash chamber rises and passes through the FIRST-STAGE VAPOR SEPARATOR into the FIRST-STAGE DISTILLING CONDENSER. The vapor condenses on the outside of the tubes and transfers its latent heat to the incoming feed. The distillate flows through the external FIRST-STAGE DRAIN REGULATOR, or a loop seal and into the bottom of the second-stage distilling condenser where a portion of it flashes to the lower pressure in the second-stage distilling condenser.

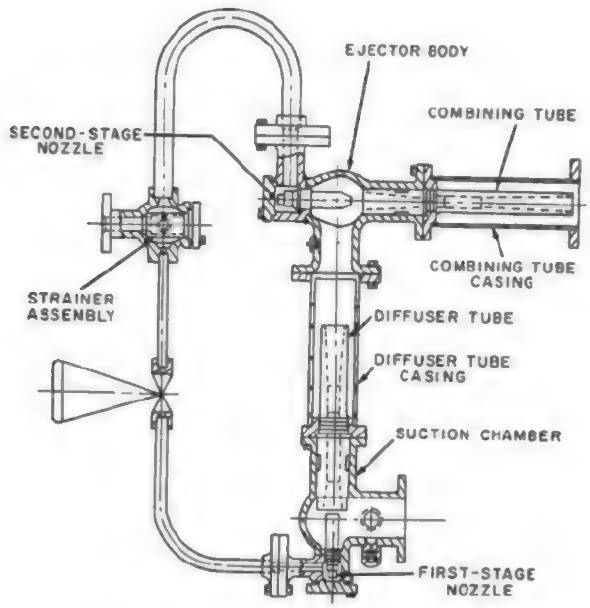
The vapor flashed from the feed in the second-stage feed box rises and passes through the SECOND-STAGE VAPOR SEPARATOR into the SECOND-STAGE DISTILLING CONDENSER. After condensing on the outside of the tubes, the distillate mixes with that from the first-stage condenser and is removed from the second-stage condenser shell by the DISTILLATE PUMP.

The discharge from the distillate pump passes through a salinity cell and the DISTILLATE FLOWRATOR into the distillate cooler where the distillate is cooled by the incoming evaporator feed water. From the cooler, the distillate passes through the salinity cell which controls the THREE-WAY SOLENOID TRIP VALVE. Depending on the purity of the distillate as it passes through the last salinity cell, the three-way valve will direct the distillate to the bilge or to the ship's fresh water system or reserve feed system.

Air Ejector System

Air and other noncondensable vapor may enter the system dissolved in the feed water, and possibly by leakage at the various vacuum joints. These noncondensable gases are removed and the required vacuum is maintained at the second-stage distilling condenser by a TWO-STAGE AIR EJECTOR. The construction of the air ejector is shown in figure 13-21.

Steam for both stages of the ejector is supplied from a 150 psi steam line. The first stage of the ejector takes its suction from the coolest portion of the second-stage distilling condenser. The gases enter the inlet of the first-stage nozzle at the mixing chamber and are entrained by the steam flowing from the nozzle. The gases are carried through the diffuser and are discharged into the mixing chamber of the second-stage nozzle. The gases are again entrained by the steam flowing from the second-stage nozzle and are carried through



47.135
Figure 13-21.—Two-stage air ejector.

the second-stage diffuser. From the second-stage diffuser the gases and steam are discharged into the AIR EJECTOR AFTER-CONDENSER. The steam is condensed by the evaporator feed water which flows through the condenser tubes. The condensate is discharged from the condenser shell, through a salinity cell, to the drain collecting system or to the bilge. The noncondensable gases are discharged to the atmosphere through the vent in the top of the condenser shell.

FIVE-STAGE FLASH UNIT

The five-stage flash unit consists of five evaporator-condenser stages in a single shell. Passages and loop seals, between the stages, permit the flow of feed water and distillate, while preserving a different vacuum in each stage.

In most instances, the feed water heater, drain regulators, air ejectors, air ejector condensers, condensate coolers, interstage distillate drain regulators, feed and distillate flow regulators, and three-way solenoid dump valves are mounted directly on the shell. The flow of the various fluids through the plant is shown in figure 13-22.

In the flashing process, the feed water gives up heat to the vapor produced in each stage, but the pressure reduction in each succeeding stage enables the flashing to continue with as much vapor produced in the final stage as in the first.

The concentrated feed water (brine) overflows through the vacuum-preserving feed water loop seals from stage to stage, becoming increasingly more concentrated in each stage until it is pumped out from the fifth stage.

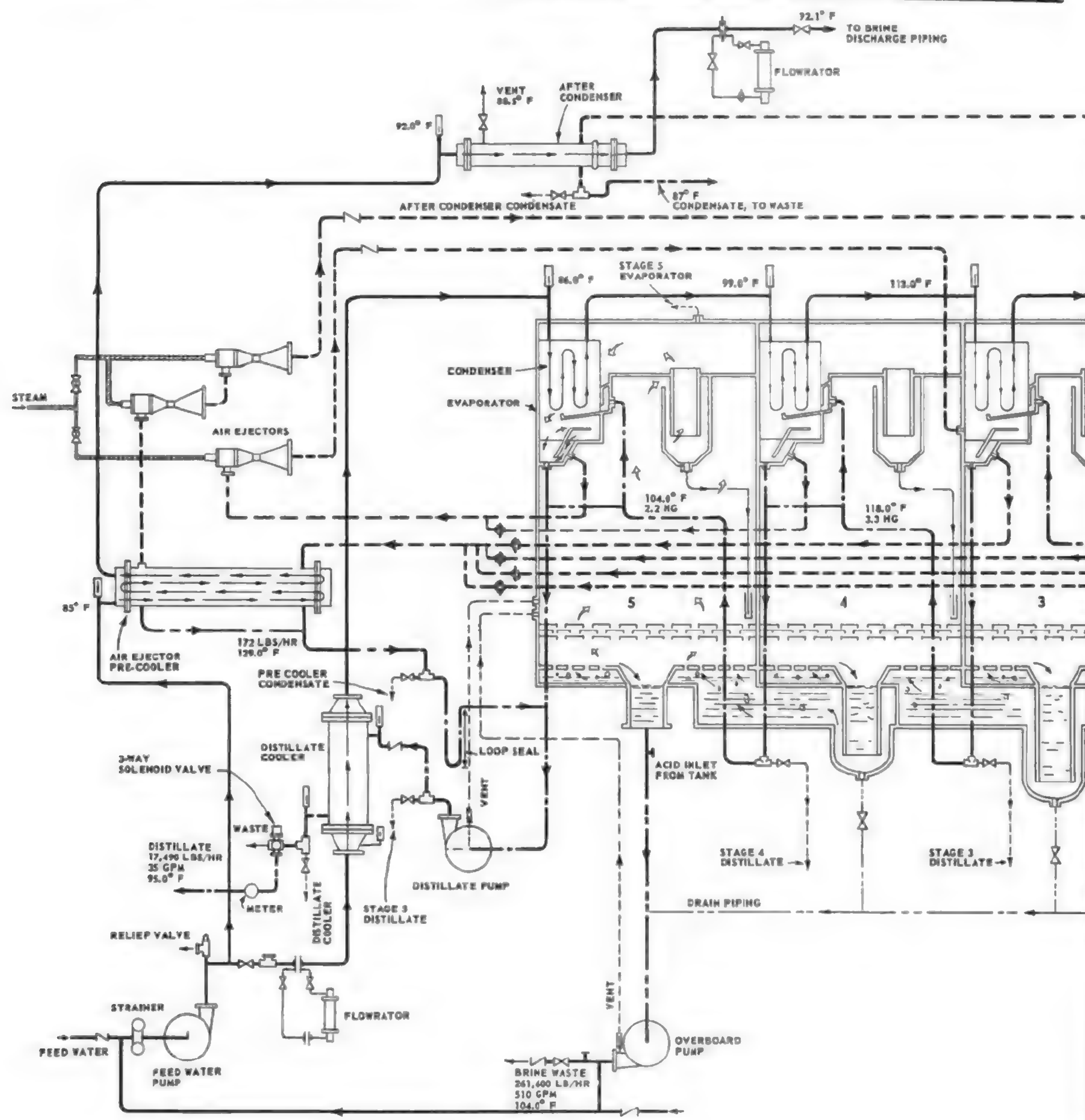
Under normal conditions, feed water is heated within the unit as it flows through the tubes of the following components: the distillate cooler, the five-stage condensers, the pre-heater, and the feed water heater. Therefore, the amount of feed water flowing through the heater must be regulated manually in order that the temperature rise of the water may be controlled.

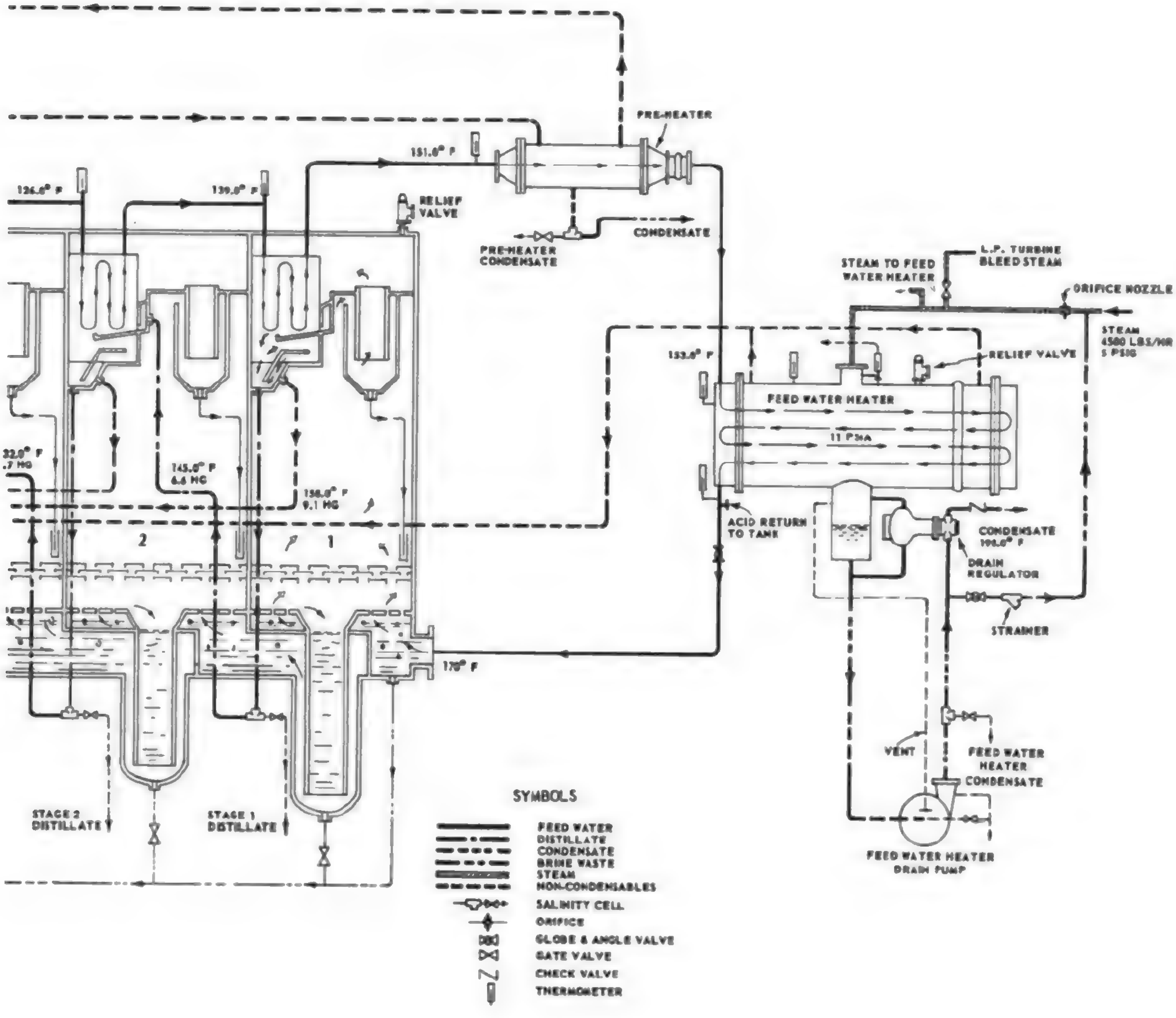
The rate of feed to the first-stage inlet box should be maintained constant at all times, providing the plant is producing its normal capacity or less. Distilling plants are designed to operate at a definite number of gallons of feed per minute, and the feed rate is indicated by the feed rotameter(s) in the feed line between the distilling condenser circulating water pump and the distillate cooler. All other valves in the feed line should be opened wide to prevent their interfering with the proper flow of feed through the plant.

With proper feed flow and with a clean plant, the temperature of the feed entering the first-stage feed inlet box will be 175° or less, depending on the temperature of the sea water. Plants are designed to operate with a feed temperature of 175° maximum when the temperature of the sea water is 85°F; when the sea water temperature is lower, the feed temperature will be correspondingly lower.

No attempt should be made to control the feed water temperature after it leaves the feed water heater and enters the first-stage flash box. The temperature should adjust itself to the varying plant conditions. Full capacity will be realized with proper feed flow, proper vacuums throughout the plant, and with proper steam pressure above the orifice.

The feed temperature should never be allowed to exceed 175°F, as temperatures above this amount will greatly increase the amount of scale formation. Such high temperatures will


92.1° F
TO BRINE DISCHARGE PIPING
FLOWRATOR
VENT
AFTER CONDENSER
92.0° F
AFTER CONDENSER CONDENSATE
87° F
CONDENSATE, TO WASTE
STAGE 5 EVAPORATOR
86.0° F
99.0° F
113.0° F
CONDENSER
EVAPORATOR
STEAM
AIR EJECTORS
104.0° F
2.2 HG
118.0° F
3.3 HG
85° F
5
4
3
AIR EJECTOR PRE-COOLER
172 LBS/HR
PRE COOLER CONDENSATE
DISTILLATE COOLER
LOOP SEAL
3-WAY SOLENOID VALVE
WASTE
DISTILLATE
17,490 LBS/HR
35 GPM
95.0° F
METER
DISTILLATE COOLER
STAGE 3 DISTILLATE
DISTILLATE PUMP
VENT
ACID INLET FROM TANK
STAGE 4 DISTILLATE
STAGE 3 DISTILLATE
DRAIN PIPING
RELIEF VALVE
STRAINER
FLOWRATOR
FEED WATER
FEED WATER PUMP
VENT
OVERBOARD PUMP
BRINE WASTE
261,600 LB/HR
510 GPM
104.0° F



96.30
Figure 13-22.—Flow diagram for a five-stage flash type distilling unit.

occur under high overload conditions or when the plant is being improperly operated.

Although the capacity of the flash type distilling plant depends on the quantity of evaporator feed water entering the first-stage feed box and the difference in temperature between the feed water entering the first stage and the vapor in succeeding stages, the capacity can be changed only by increasing or decreasing the amount of heat added to the evaporator feed water heater.

With a constant steam pressure of 5 psig above the orifice, an increase in the feed flow will decrease the temperature in the first-stage flash chamber which will also decrease the temperature of the vapor in the succeeding stages and the capacity will remain constant. Therefore, the capacity of the plant can be changed by changing the steam pressure above the orifice. Except for emergency conditions, the plant should always be operated at its normal capacity as overload conditions tend to increase the scale formation.

CHAPTER 14

DISTILLING PLANT OPERATION AND MAINTENANCE

Information dealing with the construction and principles of operation of distilling plants used by the Navy is given in chapter 13. This chapter deals with the operation and maintenance of distilling plants; these are important responsibilities of Machinist's Mates. The large quantities of pure fresh water required aboard ship make it impossible to store sufficient water for more than a few days' supply. Naval distilling plants are designed to produce distillate of very high quality. The chloride content of distillate discharged to the ship's tanks must not exceed 0.065 equivalents per million. Any distilling unit which cannot produce distillate of this quality is not considered to be operating properly. With proper operation and maintenance, distilling plants can make adequate fresh water to supply the needs of the ship.

Special restrictions are placed upon the operation of distilling units when the ship is operating in contaminated waters. Because most distilling plants operate at low pressures (and therefore low temperatures) the distillate is not sterilized by the boiling process in the evaporators and may contain dangerous micro-organisms or other matter harmful to health. All water in harbors, rivers, inlets, bays, land-locked waters, and the open sea within 10 miles of the entrance to such waters must be considered contaminated unless a specific determination to the contrary is made. In other areas, contamination may be declared to exist by the fleet surgeon or his representatives, as local conditions may warrant. When the ship is operating in contaminated waters, the distilling units must be operated in strict accordance with special procedures established by the Naval Ship Systems Command.

OPERATION

Careful starting, operating, and securing of distilling plants will, to a great extent, ensure trouble-free operation. Operating procedures, tests, inspections, and maintenance are discussed in the sections which follow.

STARTING A MANUALLY CONTROLLED PLANT

To start a low pressure submerged-tube distilling plant, when the evaporators are empty and all pumps are secured, proceed as follows:

1. Open the valves in the drain lines from the first-effect heat exchanger and from the air ejector condenser. Close the valves in the tube nest drains on succeeding effects.
2. Open all valves in the circulating water suction and discharge lines, and start the distilling condenser circulating water pump. Open all air vents on the distilling condenser head and bleed out any entrapped air, closing these vent valves as soon as the air pockets are cleared. If the distillate cooler is fitted with vents on the sea water side, open these valves until all trapped air is freed.
3. Adjust the spring-loaded back-pressure valve in the circulating water overboard lines to maintain a pressure of approximately 5 psig in the feed system.
4. Open all valves in the evaporator feed system, except the valve in the leakoff line from the outlet of the air ejector condenser. Bypass valves around any heat exchangers should remain closed. If weir level controls are provided, raise the overflow weir pipes to the highest position.
5. Fill each evaporator shell up to the top of the heat exchanger. Start the evaporator feed pump, if installed. Open all vents provided at high points in the circulating water and evaporator feed lines until all entrapped air is bled out.
6. Secure the feed valves to the first effect and between effects to prevent water from siphoning into the last effect as the vacuum is obtained.

7. Open the valve in the emergency outboard line at the feed outlet from the air ejector condenser. See that the valves in the vent lines from the first-effect steam chest are closed tightly. (The steam chest vent lines on succeeding effects should be opened wide.)

8. Close all valves in the distillate pump discharge line and in the discharge line from the brine pump. In addition, close the gland sealing line to the brine pump.

9. Start the air ejector and see that the air vent from the shell of the air ejector condenser to the atmosphere is free from obstruction. Open the gate valve in the air suction line to the air ejector to be used. If a valve is provided at the discharge side of the air ejector, see that it is open. Admit high pressure steam to the air ejector nozzle, opening the steam valve wide. See that the steam line to the air ejector nozzle is properly drained. The pressure at the nozzle must be at least that specified on the air ejector nameplate, and the steam must be dry for satisfactory operation. The air valve to the air ejector not in use should be tightly closed.

10. Check the salinity of the distillate drains from the air ejector condenser. When less than 0.25 gpg (0.065 epm), shift drains from the bilges to the boiler feed system. A full vacuum of at least 26 inches Hg should exist in all evaporator shells. A failure to obtain this vacuum indicates possible air leaks which must be eliminated.

11. When certain that the system is tight, open the first-effect steam supply valve and adjust the regulating valve to provide the required pressure (5 psig) above the orifice plate, which should be installed between the regulating valve and the tube nest. (Weight-loaded valves are adjusted by adding or removing metal disks which are provided with the valve.

12. If a first-effect heat exchanger drain pump is installed, proceed as follows:

a. Unlock the drain valve mechanism to give float operation, or close the bypass around the drain regulator.

b. When a distillate level appears in the drain regulator gage glass, open the valve (if installed) in the suction line to the drain pump and start the pump. See that the pump vent and gland sealing lines are open. If the drains to the bilges are installed ahead of the drain regulator, a water level may not appear in the drainer gage glass unless the valve in the bilge line is hand-regulated to obtain and hold a water level. If the water level continues to rise to the top of the drainer gage glass, check the speed of the pump, and check the air leakage, especially at the pump glands. Check the salinity of the tube nest drains, and when tests indicate that the drains are pure, open the drain pump discharge line to the low pressure drain main, and secure the line to the bilge.

c. Open the valve(s) venting the tube nest to the first-effect shell about one turn.

13. When a distillate level appears in the drain regulator gages on succeeding effects, open the discharge valve from each drain regulator so that the distilled water drains will be carried to the flash chamber.

14. When distillate appears in the last-effect flash chamber, start the distillate pump and open all valves in the discharge line from this pump to the test tank or solenoid operated bypass valve. The distillate pump vent and sealing water line valves should be open. If weir overflow pipes are provided, lower them to their operating positions.

15. When vapor starts passing into the distilling condenser, check the relative temperatures of the circulating water in and out of the distilling condenser. The difference should not exceed 20° F. If the difference is greater than 20° F, adjust the overboard discharge valve to increase the flow of cooling water.

16. When water appears in the gage glass on the test tank, open the valve draining the test tank to the bilge. If a solenoid bypass valve is installed, trip the valve lever so that the valve discharges to the bilge.

17. Open all valves in the brine overboard line except the brine pump discharge valve. Open the valve in the vent line between the brine pump suction and the last-effect shell, and the valve in the brine pump sealing line from the circulating or feed pump to the brine pump gland seal. Start the brine pump and open the bypass valve around the pump discharge valve about 1 1/2 turns. The brine overboard valve at the sea chest or at the connection to the circulating water overboard line should always be wide open during plant operation.

18. As the output of the plant increases, water levels in all shells will drop, the feed valves or weir level controls to each shell should be adjusted to the desired position, and all valves in the steam chest vent lines adjusted to their normal operating position (approximately one turn open). The valve in the emergency overboard line from the feed outlet of the air ejector condenser should be closed, and only opened when the first effect feed is shut off, or reduced in

warm waters for decreased output. Opening this valve slightly, under these conditions, is necessary to obtain sufficient water through the condenser to condense the air ejector steam and prevent it from blowing through the open vent to the evaporator room.

19. Check the density of the brine pump discharge with the salinometer set and adjust the control valve until the density is less than 1.5 thirty-seconds. (Higher density tends to cause scaling and salting up of brine lines. Lower densities tend to decrease the plant capacity because of excess heat pumped overboard with the brine.)

20. After steady levels have been reached in each of the evaporator shells and the brine density is constant at 1.5 thirty-seconds, the quality of distilled water may be checked. First see that the salinity indicator electrical system is energized; the meter pointer should indicate zero on the scale with the selector switch in the OFF position. Select the specific cell location where a measurement is desired and turn the selector switch to the number of that cell given in the table of cell locations. Take the temperature of the water at that point, and turn the temperature compensator so that the dial indicates (to the nearest 5°) the temperature of the water passing over the salinity cell. (The meter indicates the salt content in epm of chloride or gpg of sea salt.)

21. When the purity of the distillate is satisfactory, open the valves to the fresh water pump and at the water meter. Start the fresh water pump and secure the valve in the line draining the test tank to the bilge. When, for any reason, the salinity indicator indicates higher than 0.25 gpg (.065 epm), immediately shift the distillate to the bilges.

SECURING A MANUALLY CONTROLLED PLANT

The correct procedure for securing a manually controlled low pressure distilling plant begins by notifying the engineer officer of the watch that the evaporator plant is ready to be secured. In addition, it should be requested that the auxiliary exhaust and the air ejector steam supply lines, and the first-effect evaporator tube nest and the air ejector condenser drain lines be secured in the engineroom. When permission to secure has been received, proceed as follows:

1. Secure the valve in the steam line supplying the first-effect tube nest.
2. Secure the steam supply to the air ejector and close the air suction valve between the distilling condenser and the air ejector.
3. Secure the first-effect tube nest drain pump (when provided), and close the valves in the drain lines from the first-effect tube nest and from the air ejector condenser.
4. Secure the distillate pump, the fresh water pump, and the suction and discharge valves at these pumps.
5. Secure the valves around the water meter.
6. Open all valves, in the steam chest vent lines, wide to equalize the pressure in all the units of the distilling plant.
7. Allow the distilling condenser circulating water pump, the evaporator feed pump (when supplied), and the brine overboard pump to continue operating for approximately 15 minutes to cool the distilling plant.
8. Fill each evaporator shell until the water level is just above the top row of evaporator tubes, and secure the brine pump, the circulating water pump, and the evaporator feed pump (when supplied).
9. Close the suction and discharge valves for all pumps except the adjusting valve for the brine overboard density control.
10. Close all suction and overboard sea chest valves, and (if supplied) the valve in the brine line discharge into the circulating water overboard line.
11. Secure the feed valves to each evaporator shell.
12. Open the drain lines to the bilge, from the first-effect tube nest and from the air ejector condenser.
13. Secure the inlet and outlet valves to the drain regulators, and all valves in the vent lines into the shells from the tube nests and from the distillate, the brine, and the tube nest drain pumps.

STARTING AN AUTOMATICALLY CONTROLLED PLANT

To start an automatically controlled low pressure distilling plant, when the evaporators are empty and all pumps have been secured, proceed as follows:

1. Open wide all valves in the circulating water circuit from the sea suction to the overboard discharge.
2. Start the circulating pump. Pumps must not be run dry. Before starting any pump, make

certain that the suction, vent, and gland seal valves (where provided) are open, and that the pump casing is full of water. On centrifugal pumps, leave the discharge valve closed until after the pump has been started.

3. See that the spring-loaded back-pressure valve is properly adjusted to maintain 5 psi in the discharge line from the distilling condenser.

4. Open all air vent cocks on the distilling condenser, vapor feed heater, and air ejector condenser heads until the air is expelled, then close the vent cocks.

5. If evaporator bundles are submerged, be sure that the first-effect feed valve is closed and that the overflow weir pipes are set at their highest position. If the bundles are not submerged, see that the weirs are at their highest position, open the feed valves until the tube nests are fully covered, and then close the feed valves.

6. Open the valve in the emergency circulating water line from the air ejector condenser.

7. Open wide the second-effect evaporator tube-nest vent valve. The first-effect tube-nest vent valve should remain closed.

8. See that the first-effect tube nest and the air ejector condenser drains are directed only to the bilge, and not to the ship's tanks.

9. Open the air suction to the ejector. Open the steam supply to the ejector, making sure that the full pressure required (stamped on the nameplate) is available at the nozzle, and that the steam supply is properly drained.

10. Test the salinity of the air ejector condenser drain. When less than 0.25 gpg (0.065 epm), close the bilge drain and open the drain to the tank.

11. When the second-effect shell vacuum is about 16 inches, gradually open wide the first-effect tube-nest steam supply valve. Adjust the regulating valve to maintain a steady pressure of 5 psig. The last-effect shell vacuum should continue to increase to 26 inches or more.

12. When the distillate discharges from the first-effect drain line to the bilge, test for salinity. When satisfactory, close the bilge drain valve, set the drain valves to discharge the distillate to the return system, and open the first-effect tube-nest valve one full turn.

13. When distillate appears in the second-effect drain, see that the drain discharge valve is open, and then adjust the second-effect tube-nest vent valve to operating position (approximately one turn open).

14. When distillate appears in the flash chamber, be sure the distillate cooler discharge is directed to the bilge by manually tripping the solenoid-actuated valve. Then start the distillate pump. (The same point applies here as was given in step 2, with reference to starting a pump.)

15. The following steps should now be performed in fairly rapid sequence:

(a) Lower the overflow weir pipes to their operating positions.
(b) Start the brine pump and open all valves in its discharge line.
(c) If a loop seal of at least 8 feet has been provided in the feed line between effects, open wide the second-effect feed valve. Otherwise open it partially.
(d) Close the emergency circulating water overboard line from the air ejector condenser and open the first-effect feed valve.

16. When the salinity of the distillate leaving the distillate cooler is less than 0.25 gpg (0.065 epm), set the solenoid valve to discharge to the ship's tanks.

17. Open and adjust the feed-treatment injection valve or pump, if feed treatment is to be done.

18. After the plant is in operation about half an hour, check the density of the brine. If the density is more than 1.5 thirty-seconds, open wider the first-effect feed valves; if less than 1.5 thirty-seconds, close down on the valve. Repeat every half hour until two successive readings of 1.5 thirty-seconds are obtained. Then test at hourly intervals.

SECURING AN AUTOMATICALLY CONTROLLED PLANT

The correct procedure for securing an automatically controlled low pressure distilling plant begins by notifying the engineer officer of the watch that the evaporator plant is ready to be secured. When permission to secure has been received, proceed as follows:

1. Shut off the steam supply to the first-effect tube nest.

2. Close the first-effect tube-nest drain line to the return system, and open the drains to the bilge.

3. Close the first-effect tube-nest vent valve.

4. Close the air suction and steam supply valves to the air ejector.

5. Open wide the second-effect tube-nest vent valve.

6. Secure the distillate pump.
7. Raise the weir pipes, on both effects, to their highest positions and continue operation of the distilling condenser circulating water pump and brine overboard pump for 10 minutes or longer to cool off the distilling plants.
8. Secure the brine overboard pump.
9. When both tube nests are fully covered with water, secure the circulating pump.
10. Secure the suction and overboard sea chests.
11. Secure the feed valve to the first effect.
12. Close the air ejector and condenser drain lines to the return system and open the drains to the bilge.
13. Trip the solenoid valve in the distillate line to discharge to the bilge.

WATCHSTANDING

Proper watchstanding requires the operator to constantly check pressures, temperatures, vacuum, and salinity. Installing automatic controls does not relieve the operator of the responsibility of attentive watchstanding. The most important tests and inspections performed by the MM3 or MM2 standing distilling plant watches are discussed in the section which follows.

DISTILLATE TESTING

The fresh water (distillate) produced must meet specified standards of chloride content and purity. To ensure that those standards are met, the distillate must be tested continuously. Chloride content and purity tests are accomplished by two methods: the electrical salinity test and the periodic chemical tests.

The results of distillate tests are expressed in terms of a unit called EQUIVALENTS PER MILLION (epm). However, before explaining epm, it will be easier if you understand a unit called PARTS PER MILLION (ppm).

PARTS PER MILLION is a weight-per-weight unit denoting the number of parts of a specified substance in a million parts of water. For example, 58.5 pounds of salt in 1 million pounds of water represents a concentration of 58.5 parts per million (ppm). Note, also, that 58.5 OUNCES of salt dissolved in 1 million OUNCES of water, or 58.5 TONS of salt dissolved in 1 million TONS of water represent the same concentration—58.5 ppm.

EQUIVALENTS PER MILLION can be defined as the number of equivalent parts of a substance per million parts of water. (The word "equivalent" refers to the chemical equivalent weight of a substance.) The chemical equivalent weight is different for each element or compound. The chemical equivalent weight of sodium chloride (common table salt) is 58.5. A solution containing 58.5 PARTS PER MILLION of this salt is said to contain 1 EQUIVALENT PER MILLION. If a substance has a chemical equivalent of 35.5, a solution of that substance containing 35.5 ppm is described as having a concentration of 1 epm.

Electrical Salinity Testing

Electrical salinity cells are installed throughout the distilling plant to maintain a constant check on the distilled water. An electrical salinity indicator consists of a number of electric salinity cells in various points in the plant—in the fresh water pump discharge, distillate pump discharge, tube-nest drain, and air ejector condenser drain—connected to a salinity indicator panel on a bulkhead near the plant.

Since the electrical resistance of a solution varies according to the amount of ionized salts in solution, it is possible to measure salinity by measuring the electrical resistance. The salinity indicator panel is equipped with an ammeter calibrated to read directly in either epm or grains per gallon (gpg). Since resistance also varies with temperature, a temperature-compensator must be set at a value corresponding to the temperature of the solution.

When reading the dial of an electrical salinity indicator, be sure that you know what you are reading. Some salinity indicators are still calibrated in grains of sea salt per gallon (gpg). This unit is no longer used for reporting water analyses, so any reading taken in gpg must be converted to epm. Multiply the gpg (meter reading) by 0.261 to get the epm. For example, a meter reading of 0.75 grains of sea salt per gallon is equal to 0.75 X 0.261, or 0.196 epm.

To check an electrical salinity indicator for operation, proceed as follows:

1. Turn on the power to the indicator.
2. Set the temperature-compensator at 110° F.
3. Depress the test button and hold it down until the reading is taken.
4. Read the indicator. The reading should be approximately 1 grain. If the salinity indicator does not give a reading of 1

grain, the instrument is not correctly calibrated and should be checked by an I. C. Electrician.

Chemical Salinity Testing

This test is applied to samples of water drawn for the distilling plant distillate. Specific instructions for making the tests are generally posted on or near the water testing equipment cabinet provided in each evaporator space. The general procedure is as follows:

1. Rinse a 100-ml graduated cylinder with some of the water to be tested. Then fill the graduate to the 100-ml mark with distillate from the test tank, and pour it into a clean, dry casserole.
2. Add 5 drops of chloride indicator to the sample. The water should turn blue-violet or red, depending upon its alkalinity.
3. Using the nitric acid burette, add reagent nitric acid, one drop at a time, stirring continuously, until the violet or red color just disappears. (The water will probably be pale yellow.)
4. Now add exactly 1 ml more of reagent nitric acid.
5. Fill the mercuric nitrate burette and let it drain down to zero. Drain some to fill the burette to the tip. Then refill the burette.
6. Place the casserole under the mercuric nitrate burette and add reagent mercuric nitrate to the contents of the casserole. Stir continuously until a pale blue-violet color persists through the solution. (Add the mercuric nitrate at a fairly rapid rate at first, but add it very slowly — drop by drop — as the end point is approached.)
7. Read the burette. Take the reading from the BOTTOM of the MENISCUS (the curved surface of the liquid column). Since the sample size was 100 ml, and the burette factor is 0.25 epm of chloride per milliliter of mercuric nitrate solution, multiply the burette reading by the factor 0.25. For example, if the 100 ml water sample requires 1.75 ml of mercuric nitrate, the chloride concentration is 1.75 x 0.25, or 0.44 epm.

Test Periods And Chloride Limits

Chloride content can be determined either with the electrical salinity indicator or by the chemical method. Electrical salinity indicator readings should be checked frequently by the chemical method. Test periods and chloride limits for the various feed water constituents are as follows:

1. Condensate: main condensers, every 15 minutes while underway and every 30 minutes while standing by; auxiliary condensers, every 30 minutes; chloride limit is 0.05 epm.
2. Deaerating feed tanks and surge tanks in use: once each watch; chloride limit is 0.15 epm.
3. Reserve feed tanks: daily and for each tank just prior to being put in use; chloride limit is 0.25 epm.

CONTROL ORIFICE

Capacity control is maintained by means of an orifice in the steam supply line. The orifice controls the flow of steam to the first-effect tube nest. By maintaining a constant pressure (5 psig) above the orifice, the flow of steam into the tubes is kept constant. This results in a relatively constant distilling plant output. First-effect tube-nest vacuum automatically adjusts itself to provide the temperature difference required to condense the steam as fast as it enters. Constant capacity is desirable because it helps to provide a uniformly pure product, and ease in control of water levels and brine density.

WEIGHT-LOADED REGULATING VALVE

A weight-loaded regulating valve is installed in the steam supply line to the first-effect evaporator. The purpose of this valve is to maintain the inlet steam pressure at approximately 5 psig above the orifice. To permit free movement of the valve piston, a vent is installed at the top of the valve body. During operation, this vent must be open at all times. On some modern ships, the weight-loaded regulating valve is replaced by a diaphragm-operated control valve, actuated by an air pilot.

FEED LEVELS

The water level in each evaporator shell is controlled by hand-regulated feed valves or by overflow weirs. At the side of each evaporator

shell you can check the level in the shell by examining the gage glass or looking through the sight glass. For most efficient evaporator operation, the tube bundles should be barely covered by the boiling brine.

DESUPERHEATING OF STEAM SUPPLY

If the steam temperature below the orifice is less than 245° F, desuperheating is unnecessary. However, if the steam temperature below the orifice is above 245° F, desuperheating will be required. Desuperheating is accomplished by taking water from the first-effect tube-nest drain pump discharge and discharging through a nozzle in the steam line between the orifice and the first-effect tube nest. The desuperheating water should never be taken from the distilling plant distillate or the fresh water pump. It is likely that the entire boiler feed system will be contaminated if the distillate from the distilling plant becomes salty, since the first-effect coil drains are usually discharged into the deaerating feed tank.

The desuperheating water lowers the steam temperature to the temperature corresponding to the pressure that exists in the first-effect tube bundle.

FIRST-EFFECT TUBE-NEST VACUUM

There should be no perceptible change in the first-effect tube-nest vacuum in any one day's operation because of scale deposits on evaporator tubes. A sudden drop, or failure to obtain 14 to 16 inches of vacuum when the tubes are clean and the plant is operated at rated capacity is due to some other cause which can and must be eliminated. Do not assume, because the distilling plant output is not immediately affected, that the loss of first-effect tube-nest vacuum is not serious. No matter what the condition of the evaporator tubes, the first-effect tube-nest vacuum should be kept as high as possible. Otherwise more scale will form and the plant will have to be operated at higher temperatures. In addition, frequent cleaning will be required in order to maintain capacity.

LAST-EFFECT SHELL VACUUM

In operating the plant, it is necessary to maintain a constant last-effect shell vacuum, as a rapid fluctuation in this vacuum has a strong tendency to cause priming. It also is necessary to maintain the highest vacuum possible at all times to keep scale formation at a minimum and thus maintain capacity production for long periods without cleaning.

Obtaining maximum vacuum depends upon elimination of air leaks, proper operation of air ejectors, sufficient flow of circulating water, and the effectiveness of the heat transfer surfaces in the distilling condensers.

AIR EJECTORS

The air ejectors require very little attention during distilling plant operation. In a tight plant, only one air ejector is required to maintain a vacuum of at least 26.5 inches at the air ejector suction.

The air ejector operating pressure, stamped on the nameplate, is the minimum pressure required at the nozzle. Allowance must be made for a pressure drop in the line, through the strainer, when setting the air ejector steam reducing valve. A pressure at the nozzle, slightly higher than the minimum specified, is not objectionable unless it causes overheating of the air ejector condenser.

A low vacuum may be due to faulty operation of the ejector, but is more often due to air leakage. An unsteady vacuum, however, almost invariable indicates difficulty at the ejector. The most frequent causes are insufficient steam pressure and wet steam. A clogged strainer or nozzle may also be responsible.

VENTING EVAPORATOR TUBE NESTS

Proper venting of evaporator tube nests is very important. During normal operation of a low pressure plant, all vents leading from the steam heads to the evaporator shell should be open. When all systems of a distilling plant are operating at approximately normal temperatures and pressures, the vent valves should be adjusted so that they are open about one turn. The amount of valve opening may vary from plant to plant; therefore, the actual setting must be determined by operating experience with a particular plant.

The result of improper venting of the evaporator tube nests may be either an accumulation of air in the tubes, with a resultant loss of capacity, or an excessive loss of tube nest steam to the distilling condenser, with a loss of efficiency.

BRINE CONCENTRATION

Although the salt concentration of sea water is not always the same, the average is generally accepted as being 1 part in 32—that is, 1 pound of dissolved salts is contained in 32 pounds of sea water. As sea water is vaporized in the distilling plant, the proportion of dissolved salts becomes greater in the remaining solution. The brine concentration in the last-effect shell should be kept at 1.5 thirty-seconds—that is, there are 1.5 pounds of dissolved salts in 32 pounds of brine.

The concentration (density) of brine in the evaporator, within limits, has a direct bearing on the quality of the fresh water distilled by the plant. Since the varying quantities of brine that are discharged overboard affect the operating conditions of the plant, it is desirable to keep the quantity of brine discharged and the brine concentration in the last-effect shell as constant as possible. If the brine concentration is too low, there will be a loss in capacity and economy, and it will be difficult to obtain proper feeding. If the brine concentration is too high, there will be an increase in the rate of scaling of the evaporator tubes, and the quality of the distillate may be impaired. The brine concentration depends mainly on the quantity of brine pumped overboard and the quantity of fresh water being produced. The brine concentration should be checked frequently during each watch (usually at intervals of 1 hour).

The brine density is measured by a SALINOMETER (fig. 14-1), calibrated to read directly in thirty-seconds. The salinometer has four separate scales which indicate the salinity of the brine at four different temperatures—110°, 115°, 120°, and 125° F.

Samples of the brine are usually obtained through a sampling cock at the brine overboard pump discharge. It is important to obtain a sample truly representative of the brine in the last-effect shell. The temperature of the sample drawn into the sampling pot should agree closely with the reading of the thermometer on the last-effect shell. A difference of more than 3° or 4° F usually indicates faulty operation of the brine overboard pump, or dilution of the brine between the last-effect shell and the sampling cock.

47.136X
Figure 14-1.—Salinometer and sampling pot.

OPERATING RECORD

The Distilling Plant Operating Record (figs. 14-2 and 14-3) is a daily record of the operation of the ship's evaporators and their auxiliaries. Entries are made for each hour of the watch while the distilling plants are in operation. Different ships have different types of distilling plants, but all of the daily distilling plant operating records require practically the same data. The record form illustrated is used primarily for single shell evaporators on destroyers and destroyer escorts.

NAVSHIPS 9580/3 (REV. 2-66) FRONT
(Formerly NAVSHIPS 3676) S/N-0105-637-4100

LOW PRESSURE DISTILLING PLANT OPERATING RECORD

UNDERWAY X U.S.S. FROST - CVA 999 PLANT NO. 1

AT ANCHOR ____ TIME: ZONE DESCRIPTION PLUS 4 SET CLOCKS AHEAD OR BACK ____ MINUTES AT ____ DATE 10 JANUARY, 19 72

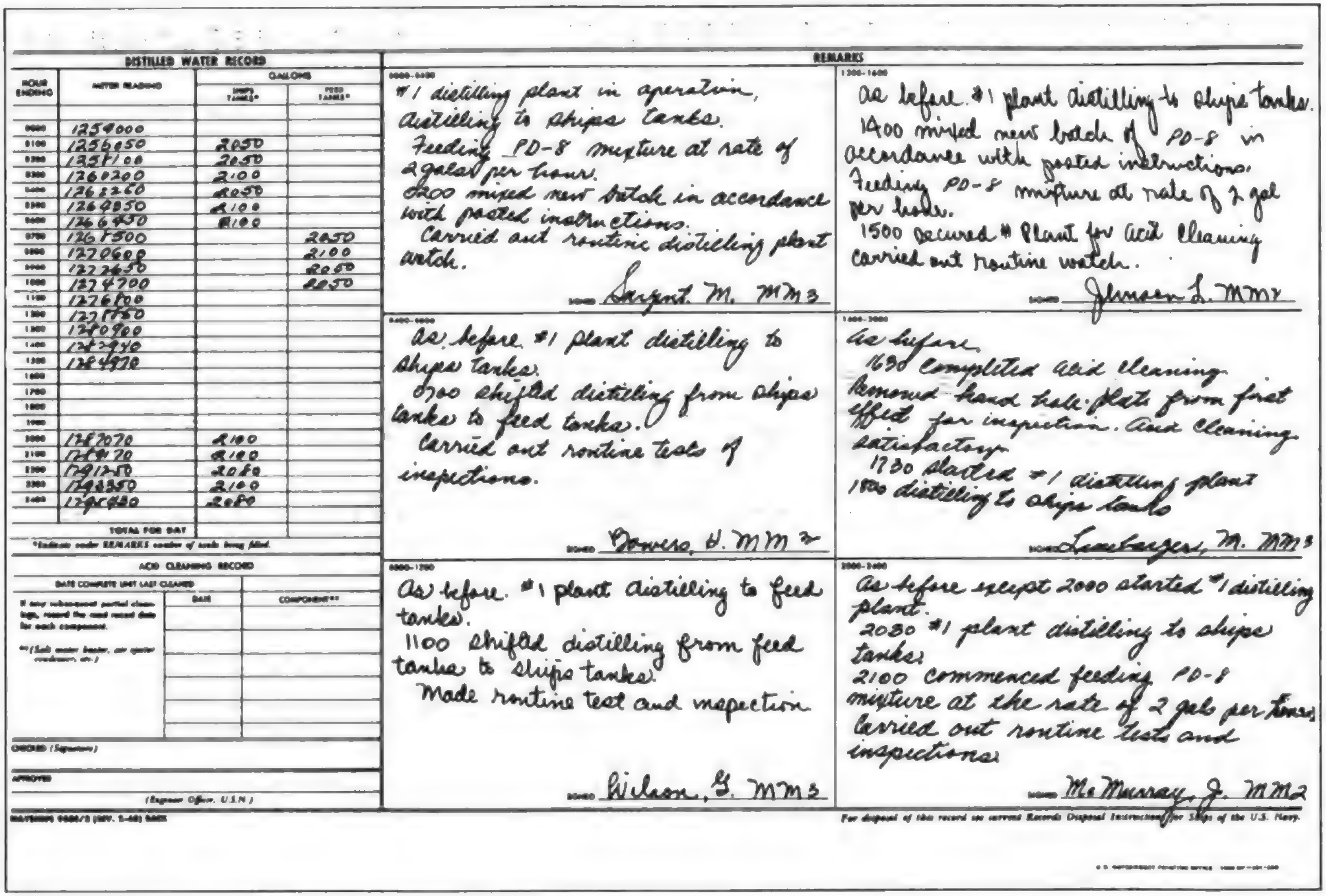
HOUR ENDING

	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200
STEAM TO REG. VALVE PRESSURE #G	15	15	15	15	15	15	15	15	15	15	15	15
STEAM FROM REG. VALVE PRESSURE #G	5	5	5	5	5	5	5	5	5	5	5	5
STEAM TO 1ST EFFECT PRESSURE HG OR #G	5	5	5	6	5	5	5	6	5	5	5	5
STEAM TO 1ST EFFECT TEMPERATURE °F	227	227	227	227	227	227	227	227	227	227	227	227
1ST EFFECT COIL DRAIN TEMPERATURE °F	212	212	212	212	212	212	212	212	212	212	212	212
1ST EFFECT SHELL PRESSURE HG	16	16	16	16	16	16	16	16	16	16	16	16
2D EFFECT COIL DRAIN TEMPERATURE °F	180	180	180	180	180	180	180	180	180	180	180	180
2D EFFECT SHELL PRESSURE HG	22	22	22	22	22	22	22	22	22	22	22	22
3D EFFECT COIL DRAIN TEMPERATURE °F	135	135	135	135	135	135	135	135	135	135	135	135
3D EFFECT SHELL PRESSURE HG	26	26	26	26	26	26	26	26	26	26	26	26
CONDENSATE TO COOLER TEMPERATURE °F	110	110	110	110	110	110	110	110	110	110	110	110
CONDENSATE FROM COOLER TEMPERATURE °F	95	95	95	95	95	95	95	95	95	95	95	95
BRINE OVERBOARD TEMPERATURE °F	125	125	126	125	125	125	125	125	125	125	125	125
STEAM TO AIR EJECTOR PRESSURE #G	135	138	131	140	140	140	140	134	134	137	134	140
AIR EJECTOR DRAINS, TEMPERATURE °F												
CIRC. WATER INJECTION TEMPERATURE °F	85	85	85	85	85	85	85	85	85	85	85	85
CIRC. WATER TO CONDENSATE COOLER, TEMPERATURE °F	85	85	85	85	85	85	85	85	85	85	85	85
CIRC. WATER TO DISTILLER CONDENSER TEMPERATURE °F	87	87	87	87	87	87	87	87	87	87	87	87
FEED TO AIR EJECTOR CONDENSER TEMPERATURE °F	121	121	121	121	121	121	121	121	121	121	121	121
FEED TO 3D EFFECT VAP. FD. HEATER TEMPERATURE, °F	132	132	132	132	132	132	132	132	132	132	132	132
FEED TO 1ST EFFECT VAP. FD. HEATER, TEMPERATURE, °F	153	153	153	153	153	153	153	153	153	153	153	153
FEED TO 1ST EFFECT TEMPERATURE °F	177	177	177	177	177	177	177	177	177	177	177	177
CIRC. WATER OVERBOARD TEMPERATURE °F	108	108	108	108	108	108	108	108	108	108	108	108
CIRC. PUMP SUCTION PRESSURE, #G	5	5	5	5	5	5	5	5	5	5	5	5
CIR. PUMP DISCHARGE PRESSURE, #G	22	22	22	22	22	22	22	22	22	22	22	22
BRINE PUMP SUCTION PRESSURE #G												
BRINE PUMP DISCHARGE PRESSURE #G												
FEED PUMP SUCTION PRESSURE #G												
FEED PUMP DISCHARGE PRESSURE #G												
1ST EFFECT DRAIN PUMP SUCTION PRESSURE #G	5	5	5	5	5	5	5	5	5	5	5	5
1ST EFFECT DRAIN PUMP DISCHARGE PRESSURE, #G	25	25	25	25	25	25	25	25	25	25	25	25
F.W. PUMP DISCHARGE PRESSURE	75	75	75	75	75	75	75	75	75	75	75	75
FEED DENSITY 32NDS	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32
BRINE OVERBOARD DENSITY 32NDS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AIR EJECTOR DRAINS SALINITY—EPM	.025	.025	.025	.025	.025	.025	.025	.025	.025	.025	.025	.025
1ST EFFECT DRAINS SALINITY—EPM	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
CONDENSATE FROM COOLER, SALINITY—EPM	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02

	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
STEAM TO REG. VALVE PRESSURE #G	15	15	15					15	15	15	15	15
STEAM FROM REG. VALVE PRESSURE #G	5	5	5					5	5	5	5	5
STEAM TO 1ST EFFECT PRESSURE HG OR #G	5	5	5					5	5	5	5	5
STEAM TO 1ST EFFECT TEMPERATURE °F	227	227	227					227	227	227	227	227
1ST EFFECT COIL DRAIN TEMPERATURE °F	212	218	212					212	212	212	212	212
1ST EFFECT SHELL PRESSURE HG	16	16	16					16	16	16	16	16
2D EFFECT COIL DRAIN TEMPERATURE °F	180	180	180					180	180	180	180	180
2D EFFECT SHELL PRESSURE HG	22	22	22					22	22	22	22	22
3D EFFECT COIL DRAIN TEMPERATURE °F	135	135	135					135	135	135	135	135
3D EFFECT SHELL PRESSURE HG	26	26	26					26	26	26	26	26
CONDENSATE TO COOLER TEMPERATURE °F	110	110	110					110	110	110	110	110
CONDENSATE FROM COOLER TEMPERATURE °F	95	95	95					95	95	95	95	95
BRINE OVERBOARD TEMPERATURE °F	125	125	125					125	125	125	125	125
STEAM TO AIR EJECTOR PRESSURE #G	140	137	137					140	138	139	140	139
AIR EJECTOR DRAINS, TEMPERATURE °F												
CIRC. WATER INJECTION TEMPERATURE °F	85	85	85					85	85	85	85	85
CIRC. WATER TO CONDENSATE COOLER, TEMPERATURE °F	85	85	85					85	85	85	85	85
CIRC. WATER TO DISTILLER CONDENSER TEMPERATURE °F	87	87	87					87	87	87	87	87
FEED TO AIR EJECTOR CONDENSER TEMPERATURE °F	121	121	121					121	121	121	121	121
FEED TO 3D EFFECT VAP. FD. HEATER TEMPERATURE, °F	132	132	132					132	132	132	132	132
FEED TO 1ST EFFECT VAP. FD. HEATER, TEMPERATURE, °F	153	153	153					153	153	153	153	153
FEED TO 1ST EFFECT TEMPERATURE °F	177	177	177					177	177	177	177	177
CIRC. WATER OVERBOARD TEMPERATURE °F	108	108	108					108	108	108	108	108
CIRC. PUMP SUCTION PRESSURE, #G	5	5	5					5	5	5	5	5
CIR. PUMP DISCHARGE PRESSURE, #G	22	22	22					22	22	22	22	22
BRINE PUMP SUCTION PRESSURE #G												
BRINE PUMP DISCHARGE PRESSURE #G												
FEED PUMP SUCTION PRESSURE #G												
FEED PUMP DISCHARGE PRESSURE #G												
1ST EFFECT DRAIN PUMP SUCTION PRESSURE #G	5	5	5					5	5	5	5	5
1ST EFFECT DRAIN PUMP DISCHARGE PRESSURE, #G	25	25	25					25	25	25	25	25
F.W. PUMP DISCHARGE PRESSURE	75	75	75					75	75	75	75	75
FEED DENSITY 32NDS	1/32	1/32	1/32					1/32	1/32	1/32	1/32	1/32
BRINE OVERBOARD DENSITY 32NDS	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AIR EJECTOR DRAINS SALINITY—EPM	.025	.025	.025					.025	.025	.025	.025	.025
1ST EFFECT DRAINS SALINITY—EPM	.02	.02	.02					.02	.02	.02	.02	.02
CONDENSATE FROM COOLER, SALINITY—EPM	.02	.02	.02					.02	.02	.02	.02	.02

47.137.1

Figure 14-2.—Distilling plant operating record: data page.


DISTILLED WATER RECORD

HOUR ENDING	METER READING	GALLONS: SHIPS TANKS*	GALLONS: FEED TANKS*
0000	1254000		
0100	1256050	2050	
0200	1258100	2050	
0300	1260200	2100	
0400	1262250	2050	
0500	1264350	2100	
0600	1266450	2100	
0700	1268500		2050
0800	1270600		2100
0900	1272650		2050
1000	1274700		2050
1100	1276800		
1200	1278850		
1300	1280900		
1400	1282940		
1500	1284970		
1600			
1700			
1800			
1900			
2000	1287070	2100	
2100	1289170	2100	
2200	1291250	2080	
2300	1293350	2100	
2400	1295430	2080	
TOTAL FOR DAY			

*Indicate under REMARKS number of tanks being filled.

ACID CLEANING RECORD

DATE COMPLETE UNIT LAST CLEANED

If any subsequent partial cleanings, record the next record date for each component.

**(Salt water heater, air ejector condensers, etc.)

DATE	COMPONENT**

CHECKED (Signature)

APPROVED

(Engineer Officer, U.S.N.)

NAVSHIPS 9600/2 (REV. 5-60) BACK

REMARKS

0000-0400
#1 distilling plant in operation, distilling to ships tanks.
Feeding PD-8 mixture at rate of 2 gals per hour.
0200 mixed new batch in accordance with posted instructions.
Carried out routine distilling plant watch.
SIGNED Sargent M. MM3

0400-0800
As before #1 plant distilling to ships tanks.
0700 shifted distilling from ships tanks to feed tanks.
Carried out routine tests of inspections.
SIGNED Bowers, H. MM2

0800-1200
As before. #1 plant distilling to feed tanks.
1100 shifted distilling from feed tanks to ships tanks.
Made routine test and inspection.
SIGNED Wilson, G. MM3

1200-1600
As before #1 plant distilling to ships tanks.
1400 mixed new batch of PD-8 in accordance with posted instructions.
Feeding PD-8 mixture at rate of 2 gal per hour.
1500 secured # Plant for acid cleaning
Carried out routine watch.
SIGNED Jensen L. MM2

1600-2000
As before.
1630 completed acid cleaning.
Removed hand hole plate from first effect for inspection. Acid cleaning satisfactory.
1730 started #1 distilling plant
1800 distilling to ships tanks
SIGNED Lineberger, M. MM3

2000-2400
As before except 2000 started #1 distilling plant.
2030 #1 plant distilling to ships tanks.
2100 commenced feeding PD-8 mixture at the rate of 2 gals per hour.
Carried out routine tests and inspections.
SIGNED McMurray, J. MM2

For disposal of this record see current Records Disposal Instructions for Ships of the U.S. Navy.

47.137.2

Figure 14-3.—Distilling plant operating record: remarks page.

The information required by this record consists of the following:

1. Feed water injection temperature.
2. Auxiliary exhaust steam pressure to the reducing valve or orifice.
3. Coil pressure, coil drain temperature, shell vacuum, and feed water temperature for each evaporator effect unit.
4. Steam inlet pressure, suction temperature, and suction vacuum of the air ejector for each evaporator unit.
5. Distillate circulating pump discharge pressure and temperature for each evaporator unit.
6. Brine temperature and density (measured in thirty-seconds) through the brine pump of each evaporator unit.
7. Meter reading for flow of fresh water distillate, quantity of distilled water produced, both chemical and electrical salinity measurement of the distilled water, and whether the water was piped to the ship's tanks or the feed bottoms.
8. Acid cleaning record for each evaporator unit, which includes the date the complete unit or component was last cleaned.
9. Time of starting and securing and the total operating time for the day for each evaporator and each unit of auxiliary machinery, including air ejectors, distillate circulating pumps, brine pumps, feed water pumps, fresh water pumps, and coil drain pumps.
10. Remarks (fig. 14-3) concerning the distilling plant operation and maintenance for each watch of the day.

It is aboslutely essential that you make accurate entries in the Distilling Plant Operating Record. Accurate entries not only help predict troubles but, should abnormal operating conditions suddenly develop, checking previous entries will aid in locating the sources of trouble.

MAINTENANCE OF LOW PRESSURE DISTILLING PLANTS

The full output of a distilling plant can be maintained for relatively long periods without interruption only if every part of the plant is kept in proper operating condition. This can be accomplished by maintaining the plant in accordance with the Planned Maintenance System. The following are some of these maintenance procedures and the approximate frequency required.

CARE OF HEAT EXCHANGER SURFACES

The output of the low pressure submerged tube distilling plant is not reduced appreciably by scale deposits on the evaporator tubes until the deposits have caused a reduction in first-effect tube-nest vacuum to 1 or 2 inches of mercury. When the first-effect tube-nest vacuum is lost entirely, the reduction in output becomes very great. Assuming the reduction in vacuum is due to scale, and is not the result of improper operating conditions, the evaporator tubes MUST be cleaned when the tube nest vacuum approaches zero. To maintain adequate output the tubes SHOULD be cleaned when the first-effect tube-nest vacuum falls below 3 inches of mercury.

When the plant is properly operated, and when the evaporator feed is treated, the interval between cleanings should be 6 months or more.

Salt water flows inside the distilling condenser tubes, air ejector condenser, and vapor feed heaters. Under some operating conditions, scale deposits may accumulate inside these tubes, particularly in the air ejector condenser and the first-effect feed heater. Every 6 months, or whenever the plant is secured for descaling evaporator tubes, the inside surfaces of these heat exchanger tubes should be inspected and cleaned if necessary. Neglect can lead to thick scale deposits which will be difficult to remove.

Scale Formation and Prevention

Very little hard scale should form in a distilling plant using sea water for feed if: feed water distribution is proper, steam pressure above the orifice is not more than 5 psi, a high vacuum is maintained, and the desnity of the brine overboard is not over 1.5 thirty-seconds.

During normal operating conditions, scale deposits will form at a certain rate on the distilling plant evaporator tubes. The rate of scaling depends upon the concentration of suspended matter and carbonates present in the sea or fresh water used to feed the distilling plant. However, the important point to remember is that excessive scaling of the evaporator tubes can be caused by improper operation of the distilling plant.

The scale deposits increase as the density of the brine in the last-effect shell increases. The brine concentration is dependent mainly

upon the quantity of brine pumped overboard and upon the amount of fresh water produced. If the brine concentration is too high, there will be an increase in the rate of scaling of the evaporator tubes, and the quality of the distillate may be impaired.

To retard the formation of scale on evaporator tubes and to minimize priming, solutions are continuously injected into the evaporators.

A chemical compound known as PD-8 EVAPORATOR TREATMENT replaces cornstarch and boiler compound for the treatment of evaporator feed water and has been accepted as the Navy standard feed treatment compound. PD-8 has proved to be superior because of its ability to prevent the formation of scale. The use of PD-8 increases the production of distilled water by decreasing the amount of time that plants must be shut down for cold shocking and scale removal.

PD-8 EVAPORATOR TREATMENT is composed of polyphosphates, lignins, and antifoam agents. The polyphosphates combine with the scale-forming particles in sea water, while the lignins keep the resulting solids dispersed and suspended. The antifoaming agents prevent foaming and help prevent scale.

Proportioning pump and tank assemblies, available from ship's parts supply segment of the naval supply system, consist of a 30-gallon mixing tank having a capacity of 24 gallons from top to bottom of the gage glass and a simplex or duplex proportioning pump having a maximum capacity of 2.5 gallons per hour per pump. Assemblies obtained directly from a shipyard may differ in the capacity of tank and/or pump. Installation instructions in the form ofSHIPALTS have been issued for all classes of ships having low pressure submerged tube or vertical basket type distilling plants installed. The required amount of PD-8 should be dissolved, by stirring, in a bucket of warm water at a temperature not to exceed 100° F. This concentrated solution is dumped into the 30-gallon mixing tank, enough cold water is added to dilute the solution to a total of 24 gallons, then the mixture should be stirred thoroughly to ensure a uniform solution. This mixing and dilution can be carried out while the pump continues to deliver PD-8 to the operating evaporator.

The simplex pump consists of one pump and one motor. The duplex pump consists of two pumps, driven by one motor, served by the same mixing tank. Duplex pumps may serve two distilling plants ONLY when the two plants have the same design distillate capacity and when these two distilling plants are located in the same compartment. In all other cases simplex pumps must be installed.

With either the simplex or duplex pump, the length of the stroke determines the pump capacity. The stroke is adjusted but is never set at less than 20 percent, as accuracy of the injection rate and lubrication of the pump plunger will be affected. If possible, the pump stroke (or strokes on a duplex pump) should be set to empty the mixing tank, from the top to the bottom of the gage glass, in exactly 24 hours. If this rate of injection should require a pump stroke of less than 20 percent, then the stroke should be set to empty the tank in less than 24 hours, preferably in 12 or 8 hours to enable easy establishment of a routine for refilling. However, if the time is 12 hours the solution will contain only half the amount of PD-8 required for a 24-hour period, and the tank must be filled twice a day. If the period of time for emptying the mixing tank is 8 hours, the solution will contain only 1/3 the required daily amount, and the tank must be filled three times each day.

If the pump stroke must be changed, the setting can be made from the indicator scale mounted on the crank arm, and verified by checking the amount of time required to empty the mixing tank. The indicator scale is calibrated from 0 to 10. If the pump has a maximum capacity of 7 gph, setting the indicator pointer on 5 will result in a delivery of 3 1/2 gph. To change the stroke, stop the pump and loosen the crankpin locknut. Watch the pointer on the indicator scale and turn the adjusting screw the required amount. Tighten the crankpin locknut and restart the pump. Check the time required to empty the tank and reset the pump stroke if necessary.

A vacuum drag injection line, used when the proportioner pump fails, runs from the mixing tank to a point downstream (vacuum side) of the feed control valve. A needle valve is installed in the line to allow the operator to make relatively fine adjustments in the amount of solution allowed to flow into the evaporator.

For submerged tube and basket type distilling plants, PD-8 should be injected into the evaporator feed system at a rate not to exceed 1 pound per 10,000 gallons per day distilling plant output. This rate of injection is required during the entire time the plant is in operation. A 4,000-gpd plant requires 4/10 of a pound for a 24-hour period. Two 12,000-gpd plants require the same

quantity as a 24,000-gpd plant, or 2.4 pounds per day.

The injection rate of 1 pound per 10,000 gallons per day is a maximum figure; the most effective figure will probably be closer to 3/4 pound. The best figure can be arrived at by reducing the amount of PD-8 for each batch. Each mixture should be tried for a week and if no scale is found on the evaporator tubes the amount of PD-8 can be reduced further. If scale forms during this trial, it will gradually crack off when the proper injection rate is established. The brine overboard density should always remain at 1.5 thirty-seconds as the density will influence the effectiveness of the PD-8.

PD-8 EVAPORATOR TREATMENT is not necessary for scale prevention in 2-stage flash type distilling plants, but the treatment has proven beneficial for units with more than two stages. In a 50,000-gpd flash type distilling plant, 6.0 pounds of PD-8 should be injected per 24-hour period.

The effectiveness of the PD-8 treatment can be checked by observing the shell temperature in the feed water heater. Changes in the shell temperature, with the same rate of flow, indicates changes in the resistance in the heat path between the steam and the feed water. Increases in the shell temperature indicate a buildup of either scale or PD-8 sludge.

In accordance with the Planned Maintenance System, the mixing tank should be drained to the bilges and flushed out with fresh water at least once each week, or more often if necessary, to prevent sludge from accumulating in the tank.

Scale Removal

As previously stated in this chapter, the evaporator tubes of a submerged tube type unit MUST be cleaned with the first-effect tube-nest vacuum approaches zero. The vertical basket type unit should be cleaned when it becomes necessary to use a steam pressure of 4 psig, or more, in the first-effect steam chest, to produce rated capacity. The flash type unit will require cleaning when it becomes necessary to use a steam pressure of 4 psig in the evaporator feed water heater. Assuming these reductions in capacity are due to scale and not the results of improper operation, an approved cleaning method should be used to remove the scale. The following are some of the approved scale removal methods:

CHILL SHOCKING.—The first-effect tube nest, in which the temperature of the tube nest is near that of the steam supply, tends to scale up more quickly than other parts of the plant. To combat this scale, some method of CHILL SHOCKING (COLD SHOCKING) the tubes is generally provided. This is done by draining the brine from all shells, then reflooding them by means of a hose line connected to a flushing pipe or flooding connection on the shell. This reflooding chills the tube nest bundles. Steam is then quickly admitted into the tubes, causing differential expansion and contraction to take place, which breaks the scale loose from the tubes.

If a feed treatment is not used, the distilling plant should be chill shocked daily. If the Navy standard feed treatment is used, daily chill shocking may be desirable; however, longer intervals are satisfactory.

Submerged Tube Type.—Chill shocking on a submerged tube type evaporator is performed as follows:

1. Secure the steam supply to the first-effect tube nest, the tube-nest drain pump and its discharge valve, the distillate pump, and the fresh water pump.
2. Open the emergency circulating water overboard valve at the outlet from the air ejector condenser and secure the first-effect feed valve.
3. Open wide all interstage feed valves. In plants which have shell drain or pump-out lines connected to the brine pump suction, unlock and open wide the valves in these lines.
4. Pump out the brine from all evaporator shells.
5. Connect a hose line to the flushing pipe or flooding connection.
6. Open the hose (water supply) valve to spray or flood the evaporator shells until the tubes in all evaporator shells are fully submerged.
7. Secure the hose valve and again pump out all evaporator shells.
8. Flood all shells again until the tubes in all shells are submerged. This second flooding is to lower the tube bundle temperature as much as possible. When the tubes are fully submerged, secure the hose valve and open quickly the steam supply valve to the first-effect tube nest. The

flow of steam will be restricted somewhat by the orifice, if installed, and should be increased by loading the weight-loaded regulating valve to produce not more than 10 psig pressure above the orifice. After the plant has warmed up, the pressure should be cut back to normal.

9. Start the pumps and regulate the water levels as necessary to put the plant in steady operation.

10. If the plant is one of the earlier installations which have chill shocking and spraying water supply from the fire and flushing main, disconnect the hose line from the flooding or flushing connection to protect the evaporator shells from possible excessive pressure. Such installations should be changed to outilize the distilling condenser circulating pump discharge at the earliest opportunity.

Handhole plates are provided on the bottom of the evaporator shells for the removal of scale which has flaked off the tubes.

Vertical Basket Type.—Scale forms on the outside of the corrugations of the vertical basket-type evaporator. The scale can be removed by cold shocking. Drain the shell and admit low pressure steam into the basket. This expands the corrugations and also dries the scale, thus making the scale brittle. Turn off the steam and admit sea water into the shell until the basket is covered by the sea water. Condensation of the steam in the basket creates a vacuum and the differential pressure causes the corrugations to contract. This loosens the scale which drops to the bottom of the shell. Clean-out holes near the bottom of the shell can be opened for removal of the scale particles.

For first effect, which has the most scale formation, is usually cold shocked about every 75 hours. Subsequent effects should be cold shocked at double this interval or more. In the case of a quadruple-effect unit, the fourth effect will probably require cold shocking only once or twice a year.

MECHANICAL CLEANING.—The capacity of a distilling plant is not appreciably reduced by scale deposits on the EVAPORATOR TUBES until the deposits have caused the first-effect vacuum to be reduced to 1 or 2 inches of mercury. When scale deposits cause the vacuum to approach zero, the tubes MUST be cleaned to keep the plant operating at its maximum efficiency. When the plant is properly operated and the feed water is treated, the interval between cleanings should be about 6 months. The evaporator tube nest must be withdrawn from the shell for the cleaning. Lifting gear suitable to the type of installation is usually provided to facilitate removing the tube nest.

Submerged Tube Type.—Some evaporators or distilling plants are provided with an overhead trolley from which the tube nest may be suspended for cleaning. Another type is provided with tracks and roller brackets which bolt to the front head of the tube nest. Chain falls can be used to handle the tube nest in small installations.

When the tube nest is withdrawn beyond the support plate, the tube-nest stop should be bolted in place to prevent accidental dropping of the rear head. The tubes are cleaned with a light scaling tool operated by a light air hammer. It should be held against the tube with moderate pressure, and moved over the entire length of the tube. Every tube in the nest must be cleaned, as missing one will impair the output of the plant and also make cleaning more difficult in the future.

A torch should never be used for descaling a tube nest made up of straight tubes. The expansion and contraction caused by the heat may cause the tubes to loosen at their joints.

After cleaning the tubes, a hydrostatic test of 50-psi should be applied to the bundle before replacing it within the shell.

When the evaporator tubes are pulled for cleaning, the DISTILLING CONDENSER, AIR EJECTOR CONDENSER, and the VAPOR FEED HEATERS should be inspected and cleaned, if necessary. Under some operating conditions, scale deposits may accumulate in these tubes, particularly in the air ejector condenser and the first-effect feed heater.

The distilling condenser on soloshell plants must be removed for inspection and cleaning. On other types of plants the distilling condenser can be inspected and cleaned by removing the heads at both ends. The air ejector condensers on all plants can be cleaned by removing both heads. The vapor feed heater tubes on practically all designs must be removed for cleaning.

The cleaning of these tube nests is accomplished by means of an extended shank drill, driven by a reversible motor at 250 or 300 rpm, or by standard tube cleaning equipment adapted for use with 5/8-inch outside diameter condenser tubes.

Flash Type.—In the flash type distilling plant, scale formation is reduced to a minimum because the feed is heated under pressure, which prevents boiling, and vapor is formed by free flushing under vacuum. The heat exchanger tubes require periodic cleaning. The tube sheet outer surfaces and tube interiors of the distilling condensers, air ejector condensers, evaporator feed water heater, and distillate cooler are accessible when the front and rear water boxes are removed. An electric or air-driven cleaning tool may then be pushed through the tubes to remove scale deposits.

CHEMICAL CLEANING.—Chemical cleaning has proven to be faster, more economical, more effective, and less detrimental to evaporator parts than mechanical cleaning. In chemical cleaning, a heated, diluted acid solution is circulated through the salt water circuits of the system. The two acids most commonly used are hydrochloric and sulfamic. In using these acids which may be harmful to personnel, observe the safety precautions.

Hydrochloric acid comes in liquid form and presents hazards in handling and storing. The use of hydrochloric acid is authorized ONLY when properly supervised by qualified naval shipyard personnel, never by ship's force alone.

Sulfamic acid comes in powdered form and is safe for storage aboard ship, when stored in the original containers. The use of sulfamic acid is authorized under the supervision of qualified tender or naval shipyard personnel. At the discretion of type commanders, individual ships may be authorized to carry sulfamic acid, and cleaning may be performed by qualified personnel in the ship's crew. Cleaning can be accomplished by passing 50-gallon slugs of solution through the feed and brine systems. This should be done while the plant is in operation and distilling to the bilge. A solution containing 100 gallons of sea or fresh water and 50 pounds of sulfamic acid powder can be injected into the distilling plant in two ways; by taking feed pump suction through a hose-valve assembly directly from a container of acid solution, or by using the plant vacuum to draw in the solution. Regardless of the method of injection used, the solution should be injected as rapidly as possible. The distilling plant should remain in operation so the solution will be heated as it passes through. The plant may be unbalanced by interruptions in flow but will settle down quickly when the feed water flow is again constant.

Careless handling of the acid solution can result in injury to personnel and equipment. The chemicals are harmful to the eyes and skin. If possible the chemicals should be handled by mechanical means rather than manually; protective clothing should be worn at all times during cleaning operations.

Naval Ships Technical Manual has a complete list of safety precautions and procedures which must be carefully followed when chemically cleaning distilling plants.

CARE OF STRAINERS

Quick-opening, flanged, basket type strainers are installed in the suction lines of the brine and circulating pumps, to prevent foreign matter from entering the pumps and piping systems of the distilling plant. The brine pump suction strainer should be inspected and cleaned when the plant is secured, and after any repairs that might cause scale to fall into the brine suction line.

The clogging of this strainer interferes with the operation of the pump, and, in a submerged-tube type plant, makes it impossible to maintain the brine density at 1.5 thirty-seconds. A clogged strainer in a flash type plant will cause the last flash stage to flood.

The circulating pump suction strainer should be inspected about once a week when at sea, and more frequently when in port. Even partial clogging of this strainer will result in a reduction in the flow of circulating water, which in turn causes a reduced vacuum. Scale will then form more rapidly on the evaporator tubes and inside the vapor feed heater and air ejector condenser tubes.

AIR EJECTOR CLEANING

The AIR EJECTOR STEAM STRAINER should be inspected regularly and cleaned whenever necessary. When a new plant is put into operation, the strainer may require cleaning daily or even more frequently, due to the foreign material in the new lines. Once the steam lines have been thoroughly flushed out, a monthly check should be sufficient. Failure to keep the strainer clean will cause a reduced or fluctuating vacuum.

Clogging or scoring of the air ejector NOZZLE can also cause a reduced or fluctuating vacuum. The nozzle can be cleaned with a piece of wood or soft wire. Do not use hard material; it will score the nozzle. A scored nozzle must be replaced with a new one.

MISCELLANEOUS CLEANING

When the distilling plant is dismantled for cleaning evaporator tubes, a number of other parts should be inspected, and cleaned if necessary. The feed water distributing pipes, flushing pipes, and separate drain lines should be removed and any scale deposits cleaned out. The hooks and troughs on the baffles should be cleaned to ensure proper drainage. The upper and lower gage glass equalizer lines, gage glass fittings, gage and sight glasses, feed lines between effects, brine lines, and brine pump impeller should all be inspected, and cleaned if necessary.

USES OF ZINCS

On the salt water side of most shell and tube heat exchangers and hull-mounted coolers on non-nuclear ships, the use of zincs to protect the metal of the unit against electrolytic (galvanic) corrosion has been discontinued. The exception is with heat exchanger components for which reinstallation of zincs has been prescribed by cognizant authority as a remedial measure.

This policy is not applicable to:

1. Nuclear ship heat exchanger applications.
2. Heat exchangers of ships built to Maritime Administration standards.
3. Zinc anodes which are installed for protection of the ship hull.

Zincs installed in the salt water circuit of condensers and other heat exchangers should be inspected and cleaned (or renewed) in accordance with the Planned Maintenance System. When the salt water side of a condenser is opened, inspecting and cleaning the zincs should be one of the first considerations. When a zinc is more than half corroded, a new one should be installed.

A casual inspection of a badly scaled zinc, especially while it is still wet, may lead personnel to believe that zinc metal instead of scale is exposed. The zinc, even though it appears to be in good condition, should be tested with a chipping hammer to learn the true condition of zinc metal. Whenever zincs are inspected or cleaned, the condition of the metallic contact between the zinc and its support should be checked.

A new type of high-purity zinc, known as ANODE ZINC, is installed on naval ships. Zinc protectors made of this material have the ability to slough off corrosion products as rapidly as they are formed. This characteristic allows the zinc to give continuous protection against galvanic action, since the zinc does not become encrusted with corrosion products.

CHAPTER 15

COMPRESSED AIR PLANTS

As an MM3 or MM2, you should have a thorough knowledge of air compressors, their construction, and care. You will find compressed air serves many purposes aboard ship, and air outlets are installed in various suitable locations throughout the ship. The uses of compressed air include (but are not limited to) the operation of pneumatic tools and equipment, diesel engine starting and control, air deballasting, torpedo charging, aircraft starting and cooling, and the operation of pneumatic control systems. Compressed air is suppled to the various systems by high pressure, medium pressure, or low pressure air compressors, as appropriate. Reducing valves reduce a high pressure to a lower pressure for a specific system.

AIR COMPRESSORS

There are a number of variations in the design and construction of air compressors. The construction and principles of operation of some of the most common types of air compressors, used on Navy ships, will be discussed in this chapter.

COMPRESSOR CLASSIFICATIONS

Air compressors are classified in various ways. A compressor may be single acting or double acting, single stage or multistage, and horizontal, angle, or vertical, as shown in figure 15-1. A compressor may be designed so that ONLY one stage of compression takes place within one compressing element, or so that more than one stage takes place within one compressing element. In general, compressors are classified according to the type of compressing element, the source of driving power, the method by which the driving unit is connected to the compressor, and the pressure developed.

1. Types of Compressing Elements.—Air compressor elements may be of the centrifugal, rotary, or reciprocating types. The reciprocating type is generally selected for capacities below 1,000 cfm and for pressures of 100 psi or above, the rotary type for capacities up to 10,000 cfm and for pressures below 100 psi, and the centrifugal type for 10,000 cfm or greater capacities and for up to 100 psi pressures.

Most of the compressors used in the Navy have reciprocating elements (fig. 15-2). In this type of compressor the air is compressed in one or more cylinders, very much like the compression which takes place in an internal combustion engine.

2. Sources of Power.—Compressors are driven by electric motors, internal combustion engines or steam turbine engines. Most of the air compressors in naval service are driven by electric motors.

3. Drive Connections.—The driving unit may be connected to the compressor by one of several methods. When the compressor and the driving unit are mounted on the same shaft, they are close coupled. Close coupling is often used for small capacity compressors that are driven by electric motors. Flexible couplings are used to join the driving unit to the compressor where the speed of the compressor and the speed of the driving unit can be the same.

V-belt drives are commonly used with small, low pressure, motor-driven compressors, and with some medium pressure compressors. In a few installations, a rigid coupling is used between the compressor and the electric motor of a motor-driven compressor. In a steam turbine drive, compressors are usually driven through reduction gears.

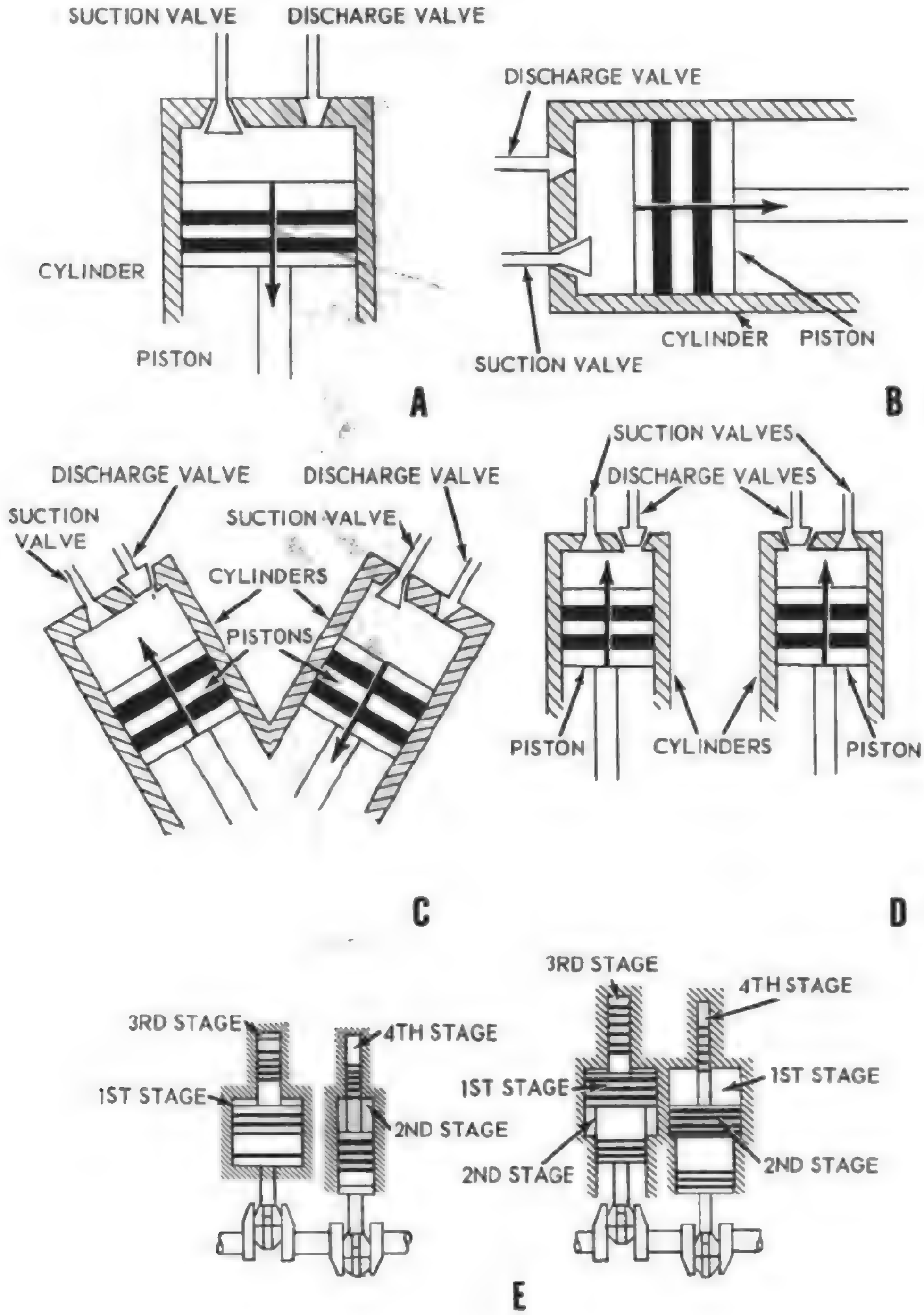


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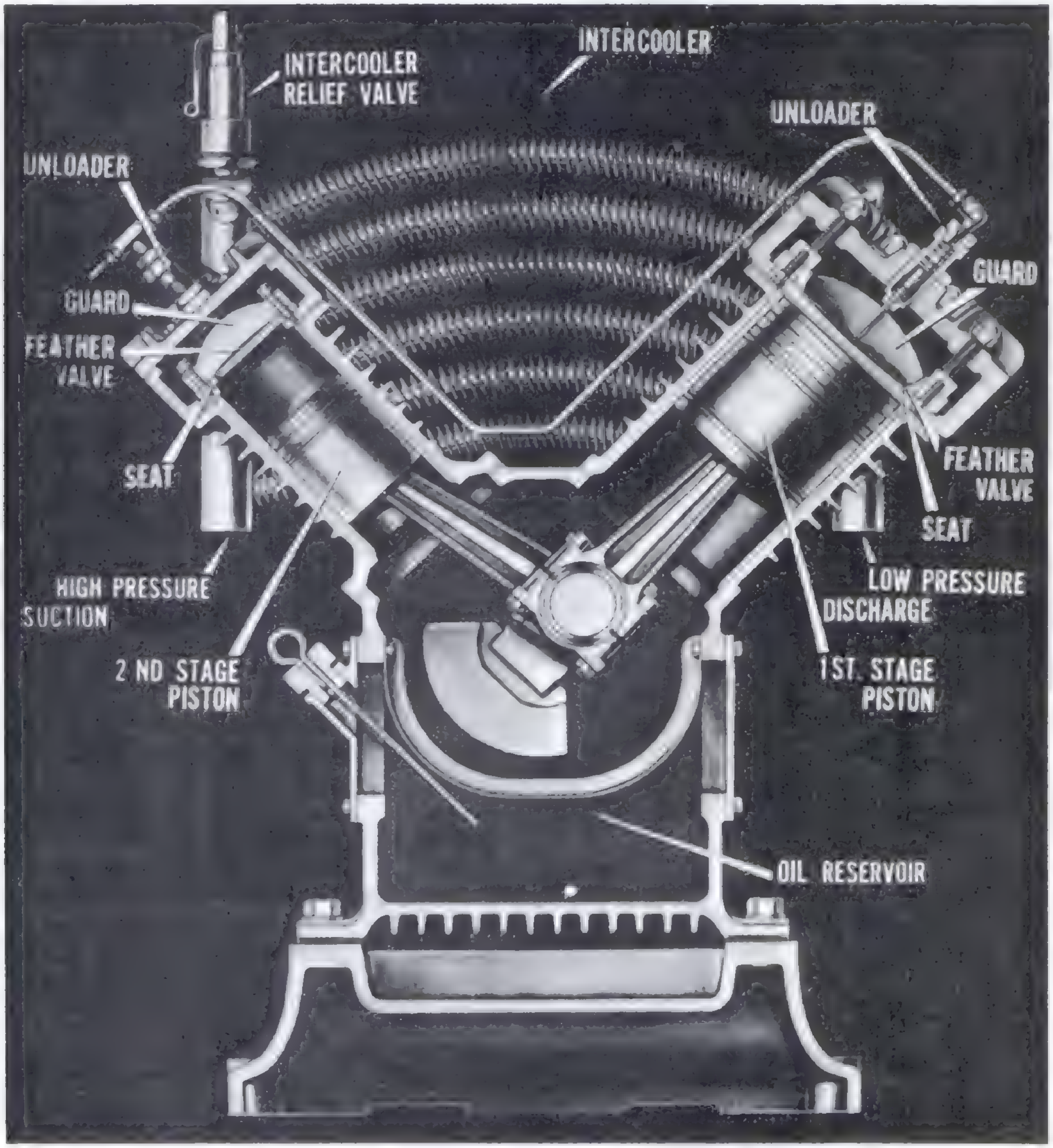
Figure 15-1.—Types of air compressors: A. Vertical. B. Horizontal. C. Angle. D. Duplex. E. Multistage.



47.152

Figure 15-2.—A simple two-stage reciprocating low pressure air compressor.

4. Pressure Classification.—In accordance with General Specifications for Ships of the United States Navy, compressors are classified as low pressure, medium pressure, or high pressure. Low pressure compressors are those which have a discharge pressure of 150 psi or less. Medium pressure compressors are those which have a discharge pressure of 151 psi to 1,000 psi. Compressors which have a discharge pressure above 1,000 psi are classified as high pressure.

Most low pressure air compressors are of the two-stage type with either a vertical V (fig. 15-2) or a vertical W arrangement of cylinders. Two-stage, V-type low pressure

compressors usually have one cylinder for the first (lower pressure) stage of compression, and one cylinder for the second (higher pressure) stage of compression. W-type compressors have two cylinders for the first-stage of compression, and one cylinder for the second stage. This arrangement is shown in the two-stage, three-cylinder, radial arrangement in part A of fig. 15-3.

Compressors may be classified according to a number of other design features or operating characteristics.

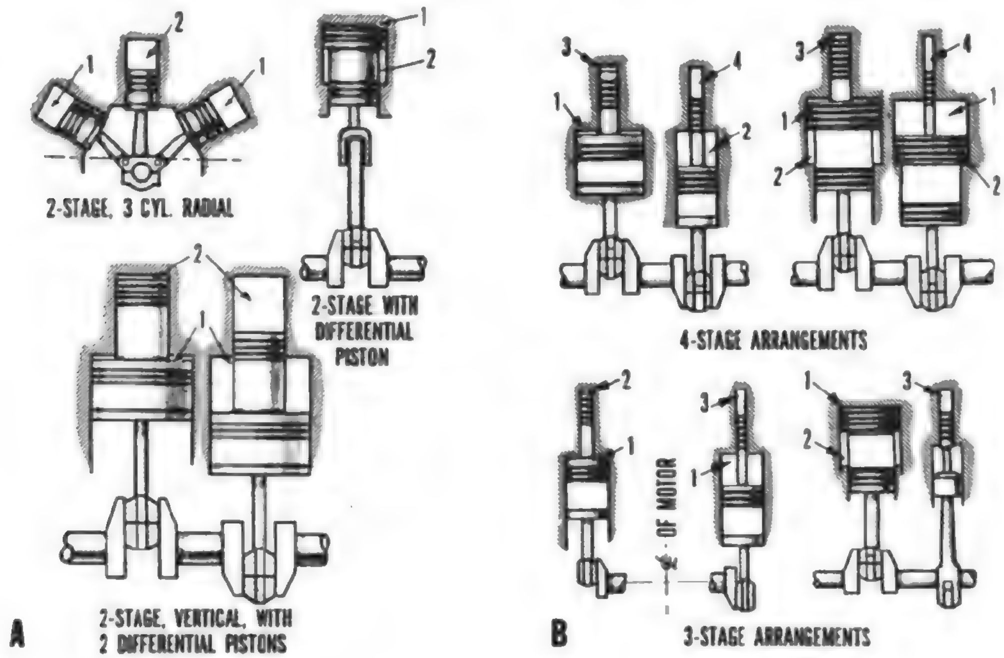
Medium pressure air compressors are of the two-stage, vertical, duplex, single-acting type. Many medium pressure compressors have differential pistons; this type of piston has more than one stage of compression during each stroke of the piston. (See fig. 15-3A.)

Modern air compressors are generally motor-driven (direct or geared), liquid-cooled, four-stage, single-acting units with vertical or horizontal cylinders. Cylinder arrangements for high pressure air compressors installed on Navy ships are illustrated in part B of figure 15-3. Small capacity high pressure air systems may have three-stage compressors. Large capacity, high pressure, air systems may be equipped with five- or six-stage compressors.

OPERATING CYCLE OF RECIPROCATING AIR COMPRESSORS

Reciprocating air compressors are usually similar in design and operation. The following discussion relates to the operating cycle during one stage of compression in a single-stage, single-acting compressor.

The cycle of operation, or compression cycle within an air compressor cylinder includes two strokes of the piston: a suction stroke and a compression stroke. The suction stroke begins when the piston moves away from top dead center (TDC). The air under pressure in the clearance space (above the piston) expands rapidly until the pressure falls below the pressure on the opposite side of the inlet valve. At this point, the difference in pressure causes the inlet valve to open and air is admitted to the cylinder. Air continues to flow into the cylinder until the piston reaches bottom dead center (BDC).



47.153
Figure 15-3.—Air compressor cylinder arrangements. A. Low and medium pressure cylinders. B. High pressure cylinders.

The compression stroke starts as the piston moves away from BDC; compression of the air begins. When the pressure in the cylinder equals the pressure on the opposite side of the air inlet valve, the inlet valve closes. Air is increasingly compressed as the piston moves toward TDC, until the pressure in the cylinder becomes great enough to force the discharge valve open against the discharge line pressure and the pressure of the valve springs. (The discharge valve opens a few degrees before the piston reaches TDC.) During the balance of the compression stroke, the air which has been compressed in the cylinder is discharged, at almost constant pressure, through the open discharge valve.

The basic operating cycle just described is repeated a number of times in double-acting compressors and in other stages of multistage compressors. In a double-acting compressor, each stroke of the piston is a suction stroke in relation to one end of the cylinder, and a compression stroke in relation to the other end of the cylinder. In a double-acting compressor, therefore, two basic compression cycles are always in process when the compressor is operating; but each cycle, considered separately, is simply one suction stroke and one compression stroke.

In multistage compressors, the basic compression cycle must occur at least once for each stage of compression. If the compressor is designed with two compressing elements for the first (low pressure) stage, two compression cycles will be in process in the first stage at the same time. If the compressor is designed so that two stages of compression occur at the same time in one compressing element, the two basic compression cycles (one for each stage) will occur at the same time. In each stage, air is compressed to the designed working pressure of that particular stage and is then discharged to the stage having the next highest working pressure, with the last stage discharging to the receiver.

COMPONENT PARTS OF RECIPROCATING AIR COMPRESSORS

Reciprocating air compressors consist of a system of connecting rods, crankshafts, and flywheels used to transmit the power developed by the driving unit to the pistons; and also consist of compressing elements, lubrication systems, cooling systems, control systems, and unloading systems.

Compressing Element

The compressing element of a reciprocating compressor consists of the air valves, the cylinder, and the piston.

The VALVES of modern compressors (except for some high pressure compressors aboard submarines) are of the automatic type. The opening and closing of these valves is caused solely by the difference between (1) the pressure of the air in the cylinder and (2) the pressure of the external air on the intake valve or the pressure of the discharged air on the discharge valve. On most compressors, a thin plate, low lift type of valve is used (fig. 15-4).

Various designs of CYLINDERS and PISTONS are used, depending primarily upon the number of stages of compression which take place within a cylinder. The three most common cylinder arrangements for low and medium pressure air compressors are shown in part A of figure 15-3. High pressure compressors with four-stage arrangements and three-stage arrangements are shown in part B of figure 15-3. The numbers 1 through 4 in figure 15-3 represent the stages of compression. Five- and six-stage compressors have the same basic stage arrangements.

The PISTONS may be of two types, trunk pistons and differential pistons. TRUNK PISTONS (fig. 15-5A) are driven directly by the connecting rods. Since the upper end of a connecting rod is fitted directly to the piston wrist pin, there is a tendency for a piston to develop a side pressure against the cylinder walls. To distribute the side pressure over a wide area of the cylinder walls or liners, trunk pistons with long skirts are used. This type of piston minimizes cylinder wall wear. DIFFERENTIAL PISTONS (fig. 15-5B) are modified trunk pistons having two or more different diameters. These pistons are fitted into special cylinders which are arranged so that more than one stage of compression is served by one piston. The compression for one stage takes place over the piston crown; compression for the other stage(s) takes place in the annular space between the large and small diameters of the piston.

Lubrication System

Lubrication of high pressure air compressor cylinders is generally accomplished by means

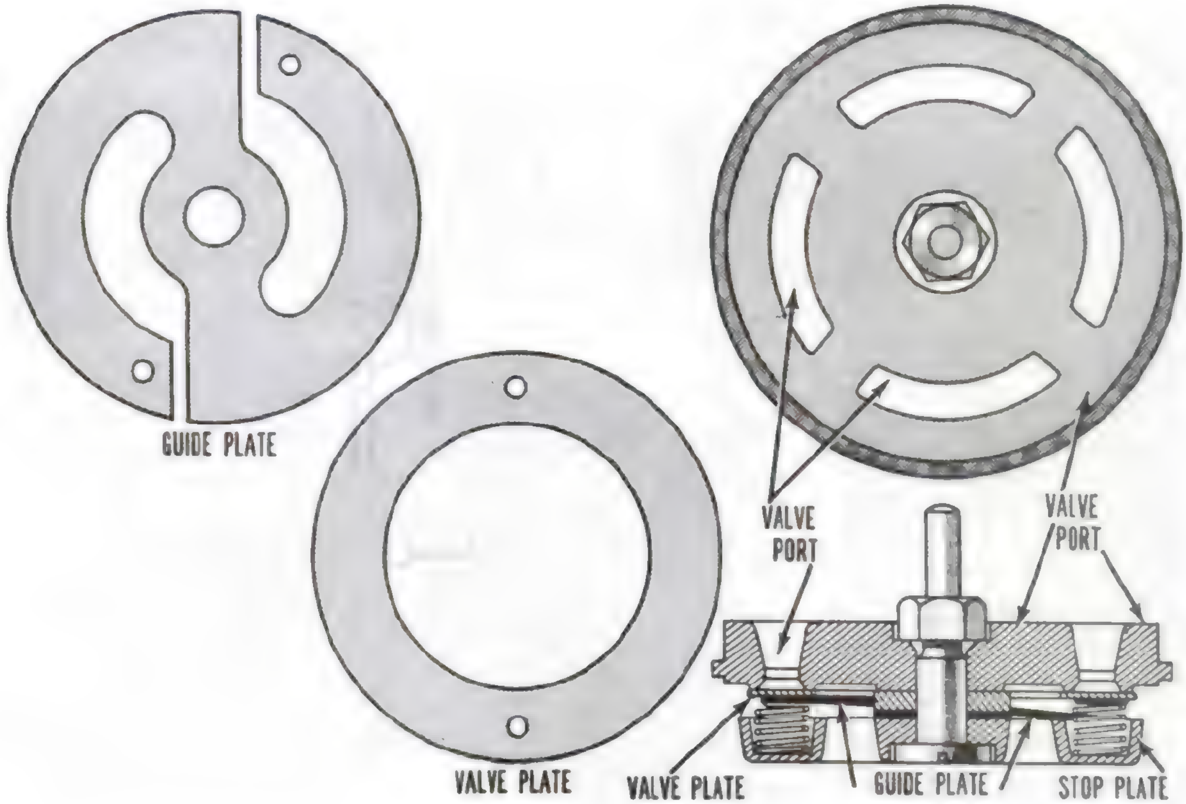


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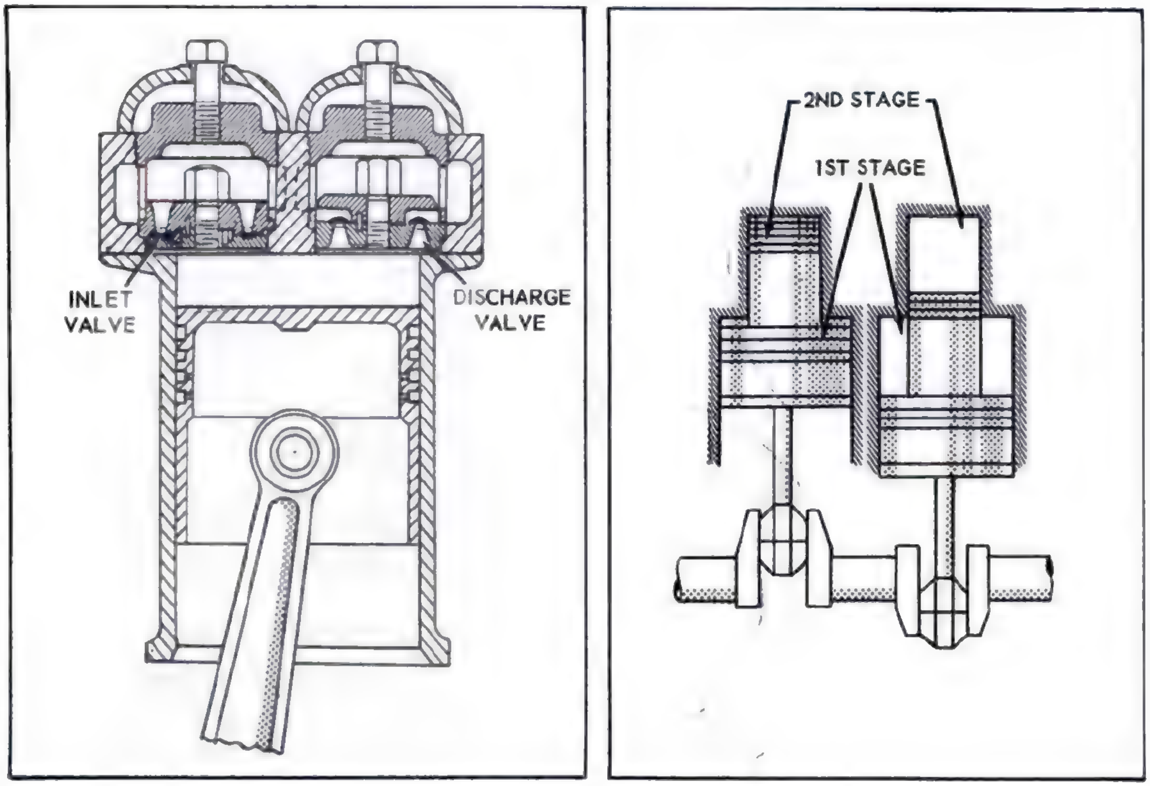
Figure 15-4.—Diagram of a thin plate air compressor valve.

of an adjustable mechanical force-feed lubricator, which is driven from a reciprocating or a rotary part of the compressor. Oil is fed from the cylinder lubricator, by separate feed lines, to each cylinder. A check valve is installed at the end of each feed line to keep the compressed air from forcing the oil back into the lubricator. Each feed line is equipped with a sight-glass oil flow indicator. Lubrication begins automatically as the compressor starts up. The amount of oil that must be fed to the cylinder depends upon the cylinder diameter, the cylinder wall temperature, and the viscosity of the oil.

In most older low pressure and medium pressure compressors, the cylinders are lubricated by the splash method, from dippers on the ends of the connecting rods or by the forced feed method whereby oil under pressure is generally forced up through a drilled passage in the connecting rod.

Lubrication of the running gear of a modern compressor is accomplished by an oil pump, which is attached to the compressor and is driven from the compressor shaft. This pump (usually of the gear type) draws oil from the reservoir (oil sump, shown in fig. 15-6) in the compressor base and delivers it, through a filter, to an oil cooler (fig. 15-6). From the cooler, the oil is distributed to the top of each main bearing, to spray nozzles for reduction gears, and to outboard bearings. The crankshaft is drilled so that oil fed to the main bearings is picked up at the main bearing journals and carried to the crank journals. The connecting rods contain passages which conduct lubricating oil from the crank bearings up to the wrist pin bushings. As oil leaks out from the various bearings, it drips back to the oil sump (in the base of the compressor) and is recirculated. Oil from the outboard bearings is carried back to the sump by the drain lines.



47.155
Figure 15-5.—Air compressor pistons. A. Trunk type. B. Differential type.

The discharge pressure of lubricating oil pumps varies with different pump designs. A relief valve, fitted to each pump, functions when the discharge pressure exceeds the pressure for which the valve is set. When the relief valve lifts, excess oil is returned to the sump.

Cooling Systems

Most high pressure and medium pressure compressors are cooled by ship's auxiliary fresh water or by sea water suppled from the ship's fire, flushing, or cooling water service mains. The cooling water is generally available to each unit through at least two sources. Compressors located outside the larger machinery spaces are generally equipped with an attached circulating water pump as a standby source of cooling water. Small low pressure compressors for ship's service and diesel engine starting, and some small capacity high pressure air compressors, are air cooled by a fan mounted on, or driven from, a compressor shaft.

The path of water in the cooling water system of a typical four-stage compressor is illustrated in figure 15-7. Not all cooling water systems have identical paths of water flow, but in systems equipped with oil coolers it is important that the coldest water be available for circulation through the cooler. Valves are usually provided so that the water to the cooler can be controlled independently of the rest of the system. Thus oil temperature may be controlled without harmfully affecting other parts of the compressor. Next in importance are the inter coolers and after coolers, then come the cylinder jackets and heads. The high pressure air compressors require from 6 to 25 gallons of cooling water per minute, while medium pressure air compressors require from 10 to 20 gallons per minute.

When sea water is used as the cooling agent, all parts of the circulating system must be of corrosion-resisting materials. The cylinders and heads are therefore composed of gun metal or valve bronze composition, with water jackets

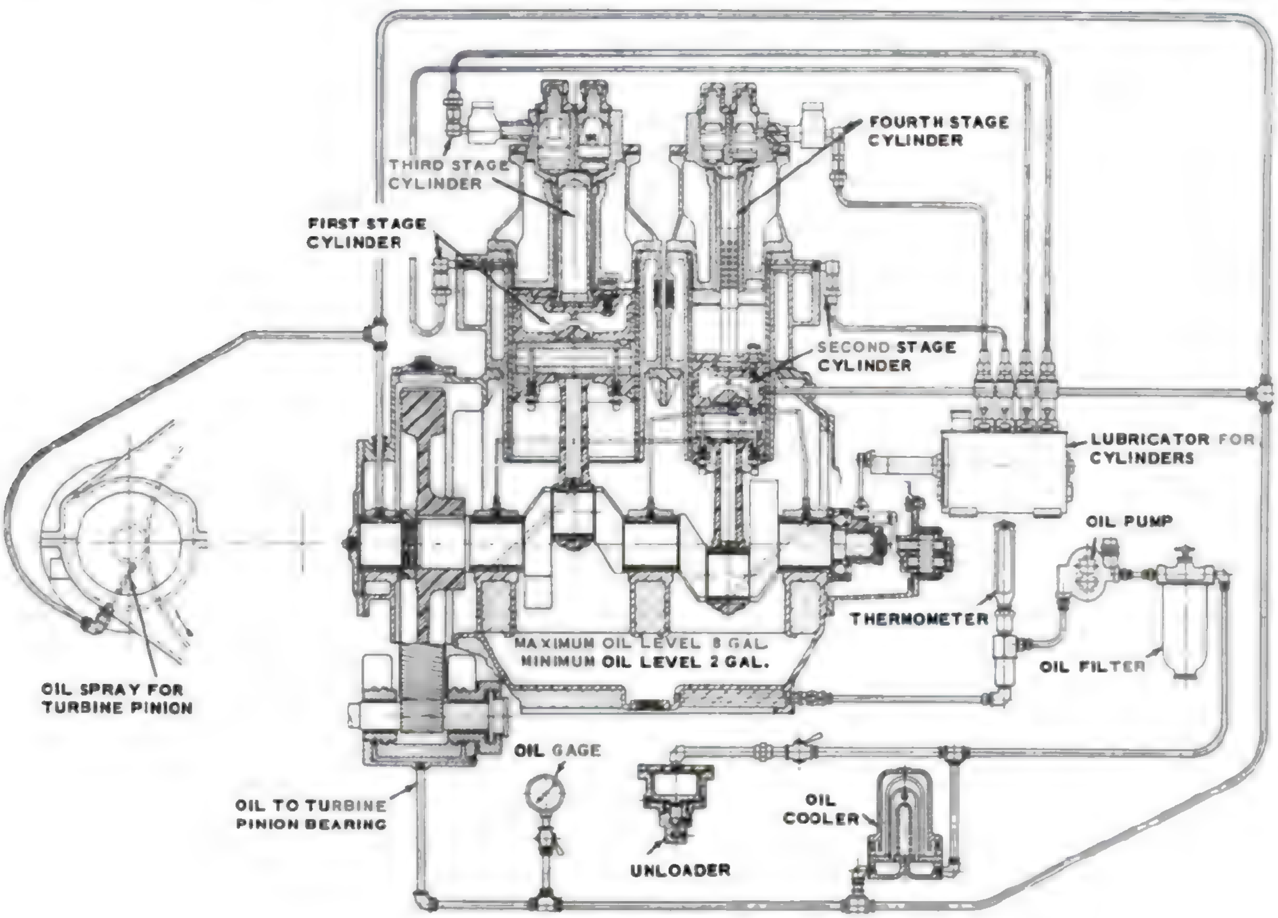


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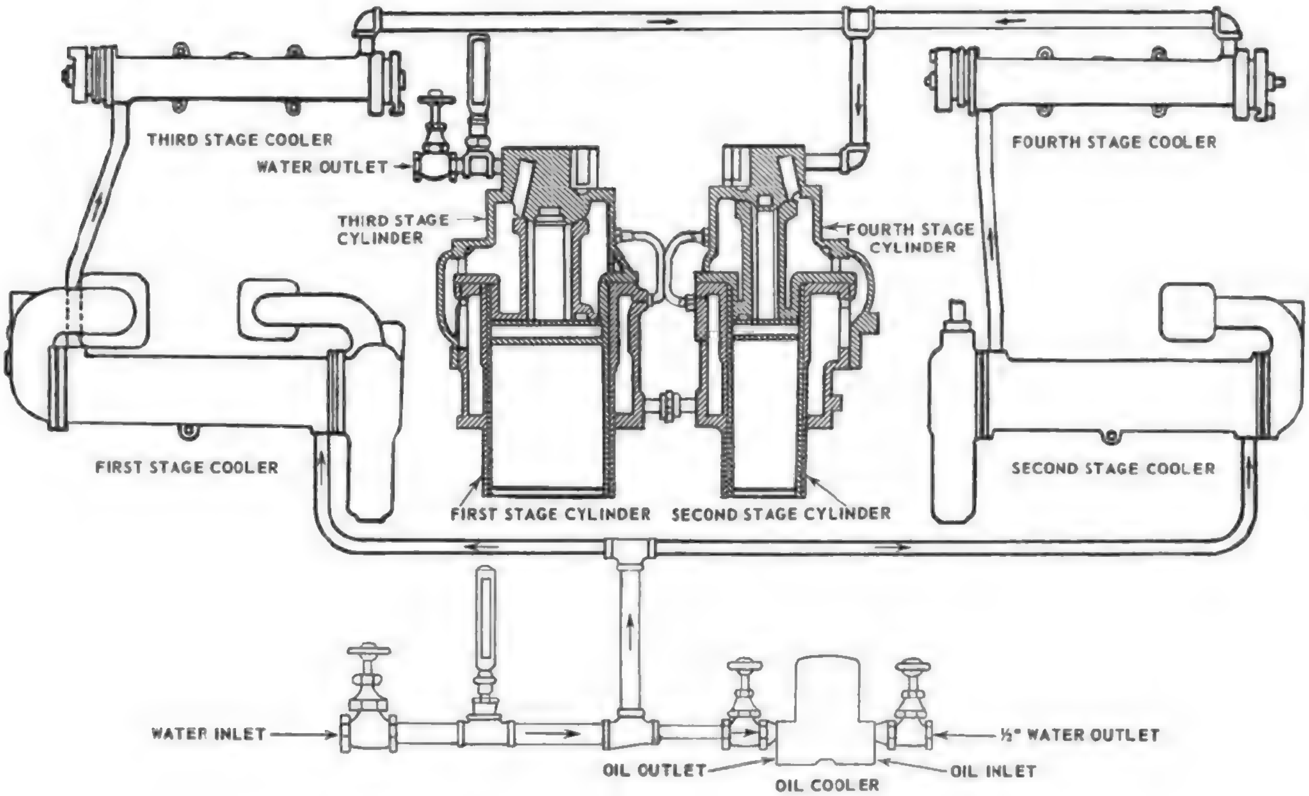
Figure 15-6.—Lube oil system of a typical multistage turbine-driven high pressure air compressor.

cast integral with the cylinders. Each cylinder is generally fitted with a liner of special cast iron or steel to withstand the wear of the piston. Wherever practicable, cylinder jackets are fitted with handholes and covers so that the water spaces may be inspected and cleaned. Jumpers are generally used to make water connections between the cylinders and heads, since these prevent any possibility of leakage into the compression spaces. In some compressors, however, the water passes directly through the joint between the cylinder and the head. With this latter type, extreme care must be taken to ensure that the joint is properly gasketed to prevent leakage which, if allowed to continue, would ruin both the cylinder liner and the piston rings.

The INTER COOLERS and AFTER COOLERS remove the heat generated during compression and cause the condensation of any vapor that may be present. It is important that this condensate be drained at regular intervals to prevent carryover into the next stage, accumulation at low points, water hammer, freezing or bursting of pipes in exposed locations, faulty operation of pnuematic tools, and possible damage to electrical apparatus where air is used for cleaning. The removal of heat is also required for economical compression. During compression the temperature of the air is increased, thus causing the air to expand to a larger volume which, in turn, requires a corresponding increase of work to compress it. Multistaging, therefore, with interstage cooling of the air, reduces the power requirement for a given capacity. The interstage cooling reduces the maximum temperature in each cylinder and thereby reduces the amount of heat which must be removed



47.157

Figure 15-7.—Cooling water system in a typical multistage air compressor.

by the water jacket at the cylinder. Also, the resulting lower temperature in the cylinder ensures better lubrication of the piston and the valves. Both the inter coolers and the after cooler are of the same general construction except that the after cooler is designed to withstand a higher working pressure than the inter coolers.

Water-cooled inter coolers may be of the straight tube and shell type or, if size dictates, may be of the coil type. In coolers where air pressure is below 250 psi, the air generally flows either through the tubes or over and around them. In coolers where air pressure exceeds 250 psi, the air generally flows through the tubes. Suitable baffles are provided in tubular coolers to deflect the air or water in its course through the cooler. In coil-type coolers the air passes through the coil, with the water flowing around the coils. Suitable provision is made for the expansion of the tube nest.

Air-cooled inter coolers and after coolers may be of the radiator type or may consist of a bank of finned copper tubes located in the path of blast air supplied by the compressor fan.

Each inter cooler and after cooler is generally fitted with relief valves on both the air and water sides. Water relief valves are generally set at 5 psi in excess of the maximum working pressure which may be applied to the system. The air relief valves must be kept set in accordance with directions given in the Planned Maintenance System, manufacturer's technical manual, or in the Naval Ships Technical Manual.

Inter coolers and after coolers are generally fitted with moisture separators on the discharge side to remove the condensed moisture and oil from the air stream. The separators are of a variety of designs. The removal of liquid is accomplished by centrifugal force, impact, or sudden changes in velocity of the air stream. Drains are provided on each separator for removing the water and oil.

Oil coolers are of the coil type, tube and shell type, or of a variety of commercial types. External oil coolers are generally used but some naval compressors are fitted with a base type oil cooler in which cooling water is circulated through a coil placed in the oil sump. As with the inter coolers and after coolers, the materials of the tubes, coils, or cores of these coolers, are of a copper-nickel alloy with shell and tube sheets of bronze composition. On all later model compressors the circulating water system is so arranged that the quantity of cooling water passing through the oil cooler may be regulated without disturbing the quantity of water going to the cylinder jackets, inter coolers, or after coolers. Thermometers or other temperature measuring devices are fitted to the circulating water inlet and outlet connections, the intake and discharge of each stage of compression, the final air discharge, and the oil sump.

Control Systems

The control system of a reciprocating air compressor may include one or more devices such as automatic high temperature shutdown devices, start-stop controls, constant speed controls, and speed-pressure governors.

AUTOMATIC HIGH TEMPERATURE SHUTDOWN DEVICES are fitted on all recent designs of high pressure air compressors. Thus, if the cooling water temperature rises above a safe limit, the compressor will stop and will not restart automatically. Some compressors are fitted with a device that will shut down the compressor if the temperature of the air leaving any stage exceeds a preset value.

Control or regulating systems for naval air compressors are mainly of the start-stop type, in which the compressor starts and stops automatically as the receiver pressure falls or rises within predetermined limits. On electrically driven compressors the system is very simple—the receiver pressure operates against a pressure switch that opens when the pressure upon it reaches a given limit, and closes when the pressure drops a predetermined amount.

On steam-driven compressors the receiver pressure is piped to a control valve (also known as a pilot, trigger, or auxiliary valve) which, when the designed cutoff pressure is reached, admits air to a plunger connected with the turbine governor valve. This causes steam to be shut off and the compressor to stop. When the pressure falls to a predetermined level, the control valve closes, and the air acting upon the plunger is released by leakage or bleeding to the atmosphere. The steam is thereby permitted to flow through the governor valve and restart the turbine.

On electrically driven units required to start at either of two pressures, as in some medium pressure systems, control is accomplished by employing two pressure switches and a three-way valve or cock so arranged that the air accumulator (receiver) pressure can be admitted to the pressure switch with the desired range of settings. Another method is to direct the air from the receiver through a three-way valve to either of two control valves set for the respective range of pressures. To do this, a line is run from each control valve to a single pressure switch which may be set at any convenient pressure since the setting of the control valve selected will determine the operation of the switch.

On steam-driven units required to start at either of two pressures, the arrangement is similar to that of the electrically driven units except that the air from the control valve selected is directed to the plunger which operates the turbine governor valve.

The CONSTANT SPEED CONTROL is a method of controlling the pressure in the air receiver by controlling the output of the compressor without stopping or changing the speed of the unit. This control is used to prevent frequent starting and stopping of compressors when there is a fairly constant but light demand for air. Control is provided by directing air to unloading devices through a control valve set to operate at a predetermined pressure.

Combined SPEED AND PRESSURE GOVERNORS are usually furnished for reciprocating steam-driven compressors, where neither the start-stop nor the constant speed control is very satisfactory.

Unloading Systems

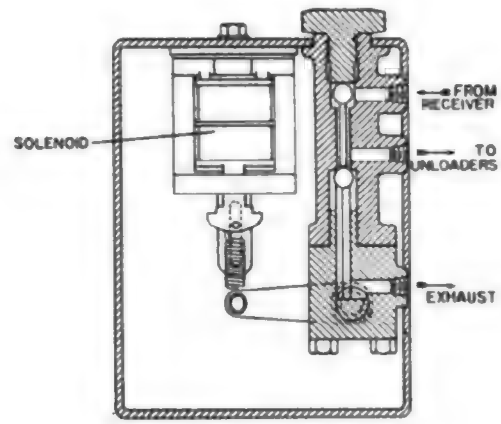
Air compressor unloading systems are installed for the removal of all but the friction loads on the compressors; that is, they automatically remove the compression load from the compressor while the unit is starting, and automatically apply the load after the unit is up to operating speed. For units having the start-stop control, the unloading system is separate from

the control system. For compressors equipped with the constant speed control, however, the unloading and control systems are integral parts of each other.

A detailed explanation cannot be given here for every type of unloading device used to unload air compressor cylinders, but you should know something about several of the unloading methods which you will probably encounter. These include closing or throttling the compressor intake, holding intake valves off their seats, relieving inter coolers to the atmosphere, relieving the final discharge to the atmosphere (or opening a bypass from the discharge to the intake), opening up cylinder clearance pockets, using miscellaneous constant speed unloading devices, and the employment of various combinations of these methods.

As an example of a typical compressor unloading device, consider the MAGNETIC TYPE UNLOADER. Figure 15-8 illustrates the unloader valve arrangement. This type of unloader consists of a solenoid-operated valve connected with the motor starter. When the compressor is at rest, the solenoid valve is deenergized, admitting air from the receiver to the unloading mechanism. When the compressor approximates normal speed, the solenoid valve is energized, releasing the pressure from the unloading mechanism and loading the compressor again.

For detailed information on the various unloading devices, refer to the pertinent manufacturers' technical manuals for compressors installed on your ship.



47.158
Figure 15-8.—Magnetic type unloader.

COMPRESSED AIR RECEIVERS

An air receiver is installed in each space housing air compressors. The receiver acts as a supply tank and a storage tank. If demand is in excess of compression capacity, some of the stored air goes into the system. If demand is less than the compressor capacity, the excess is stored in the receiver or accumulator. Thus, in a compressed air system, the receiver functions to minimize pressure variations in the system. This will thereby minimize start-stop cycling of air compressors equipped with pressure sensing controls. The receivers may be horizontal or vertical. The vertically mounted ones have convex bottoms to permit proper draining of accumulated moisture, oil, and foreign matter. All receivers include such fittings as inlet and outlet connections, drain connections and valves, connections for operating a line to compressor regulators, pressure gages, relief valves (set at 10 percent above normal working pressure of the receiver), and handhole or manhole plates (depending upon the size of the receiver). The discharge line between the compressors and the receiver is as short and straight as possible to eliminate vibration due to pulsations of the air and to reduce pressure losses due to friction.

In the high pressure air systems, AIR FLASKS are used as the air receivers. The air flasks are usually cylindrical in shape having belled ends and female-threaded necks. The flasks are also constructed in shapes to conform to the hull curvature for installation between hull frames.

TYPICAL LOW PRESSURE AIR COMPRESSORS

Having considered the various parts which make up an air compressor, you may now follow the path of air through a typical compressor. Figure 15-9, as an example, illustrates various views of a radial, single-acting, three-cylinder, two-stage, motor-driven, low pressure air compressor with a V-belt connected flywheel, air-cooled cylinders, and air-cooled inter coolers and after coolers.

Atmospheric air is drawn in through the two air inlet filters and then through the inlet or suction valves of the two first-stage cylinders as the two first-stage pistons are on their downward or suction stroke. As the first-stage

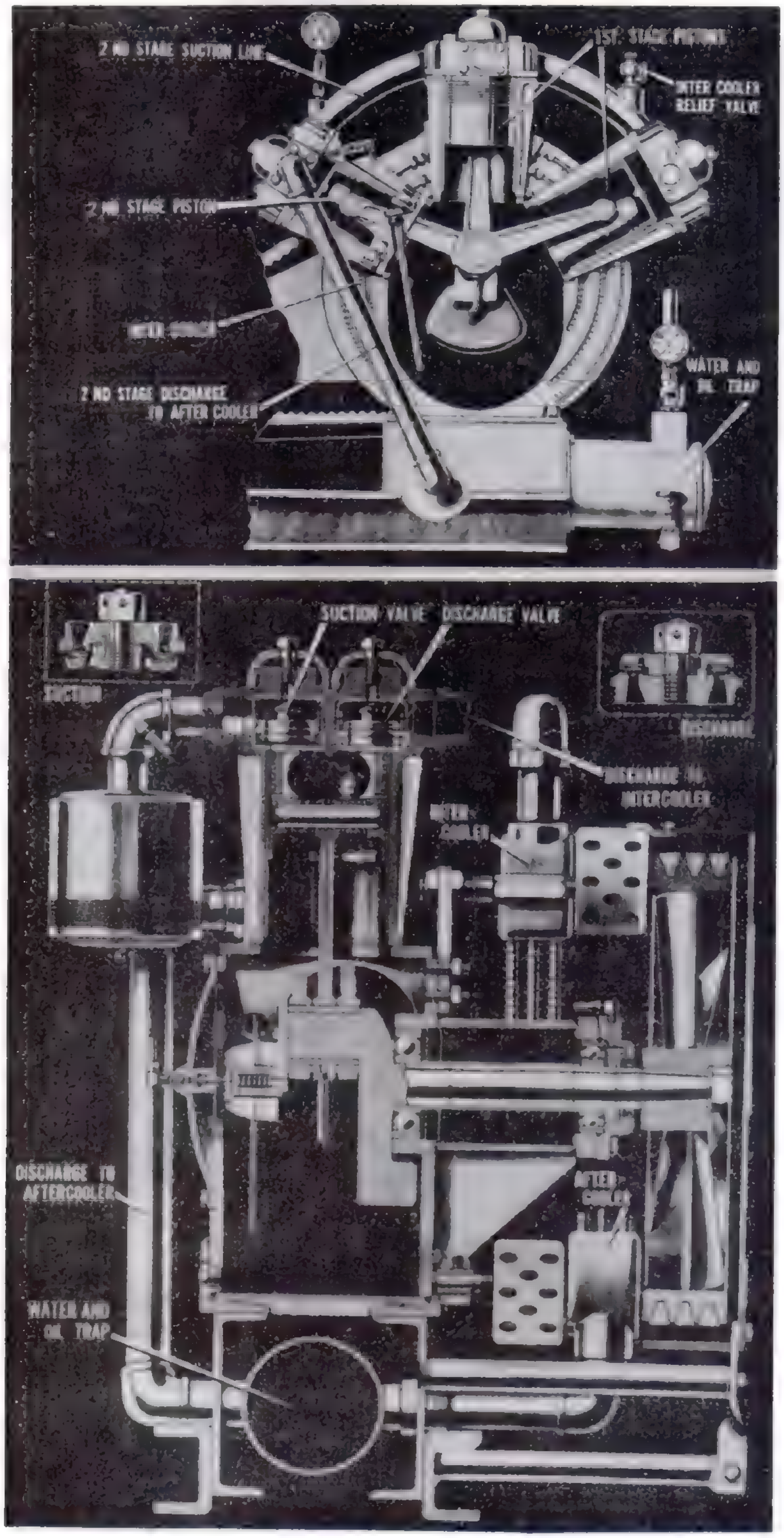


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Figure 15-9.—Typical, radial, single-acting, three-cylinder, two-stage, motor-driven, air-cooled, low pressure, air compressor.

pistons are sent on their upward or compression stroke, by action of the crankshaft, the air is compressed in the two cylinders and forced out of the discharge valves. The fins on the outside of the cylinders distribute the compression heat over a larger area, and therefore facilitate the removal of heat by the cooler air directed on them by the flywheel fan.

The discharged compressed air is directed from the discharge valves on the first-stage cylinders, through the first-stage discharge line, to the air-cooled inter cooler. In the inter cooler, the first-stage compressed air loses most of its heat by passing through coils surrounded by cooler air. From the inter cooler, the compressed air is discharged, through the second-stage suction line, into the suction valve of the second-stage cylinder. Here the air is further compressed to the designed pressure, and then forced through the discharge valve, the second-stage discharge line, and the water and oil trap, to the after cooler, where the second-stage compression heat is removed. From the after cooler, the compressed air is discharged into the air receiver.

OPERATING AN AIR COMPRESSOR

Before attempting to operate any air compressor for the first time, be sure that you are thoroughly familiar with the machine. Study the manufacturer's technical manual. There are numerous varieties of compressors in naval use, so that it would be impossible in the limited space of this training manual to present the operating procedures for each type of compressor. The following operating procedure is of a general nature.

STARTING A COMPRESSOR

In starting a compressor:

1. Inspect and clean the compressor exterior. Tighten any loose nuts, including foundation bolts. Remove any loose equipment that may be lying around.

2. Check the oil sump and (if necessary) fill to the proper level with the correct grade of oil. Prime the oil pump and lubricator.

3. Set the overspeed tripping device (if provided).

4. Jack the compressor over by hand. (Be sure the power is off and the jacking bar is removed.)

5. Turn on cooling water to the cooling system. Vent the system.

6. Open all air system stop valves.

7. Open all separator drains and remove all accumulations of moisture or oil from the separators. These should remain open until the compressor is running.

8. When the compressor is up to normal speed, gradually put a load on the compressor by closing the separator drains and indicator cocks, taking care to close those connected with the first stage, and then those connected with the second stage. If the compressor is fitted with additional stages, continue progressively through those stages.

OPERATING A COMPRESSOR

In operating a compressor:

1. After the compressor has been in operation a few minutes, recheck the oil level in the sump; if it has fallen appreciably, add sufficient oil to bring the level to normal.

2. Drain the receivers and accumulators at least once each watch.

3. Adjust the flow of cooling water so as to cool the air properly between stages. For compressors using salt water for cooling, the air leaving the after cooler should not exceed the temperature of the cooling water inlet by more than 20° F. When operating a HP air compressor, the temperature of the air leaving any stage should not exceed 400° F., for most installations, however, the temperature will not exceed 300° F.

4. Drain the inter cooler and the after cooler separators frequently.

5. Check the amount of oil being fed to the air cylinders, and adjust in accordance with manufacturer's instructions. If no information is available, 1 to 10 drops of oil per minute may be considered satisfactory for naval compressors having cylinder diameters up to 10 inches.

6. Check the operation of all relief valves regularly—use the hand levers; when provided.

7. Observe the pressure gages and thermometers frequently while the compressor is in operation.

CARE OF AIR COMPRESSORS

To keep the ship's air compressors operating efficiently at all times, you must know what common troubles may be expected and their causes; how to care for the air intakes; how to maintain and replace air valves; how to take care of the air cylinders and pistons; how to adjust bearings, wrist pins, couplings, etc.; and how to take care of the lubrication, cooling, control, and air systems.

AIR INTAKES

A supply of clean, cool, dry air is essential to the satisfactory operation of compressors. To ensure this, the AIR INTAKE FILTERS must be regularly inspected and cleaned; otherwise, the filter becomes clogged and causes loss of capacity. To clean, remove the filter element and subject it to a jet of hot water or steam, or plunge it into a strong solution of sal soda. The filter body should be drained and replaced. If the filter is the oil-wetted type, dip it in clean, medium grade oil and allow it to drain thoroughly before replacing the filter in the intake. Do not use gasoline or kerosene for cleaning filters: fumes may collect and explode in the compressor or receiver.

Care must also be taken to prevent entrance of rain or spray into INTAKE PIPES, and means should be provided for draining the intake pipe of any water which may collect. The lines should be as short and direct as possible.

CYLINDERS AND PISTONS

The cylinders and pistons should be inspected only after the manufacturer's technical manual has been consulted. Care should be taken when removing heads, particularly where metal-to-metal joints are involved, to prevent damage to the joint. Where joints are fitted with a gasket, the gaskets can occasionally be saved by running a knife blade in between the gasket and head, after the head has been lifted not over 1/4 inch.

If REPLACEMENT OF PISTON RINGS is required because they are worn or broken, accurate measurements of the cylinder liners should be taken. Standard size rings may be used in oversize cylinders if the oversize does not exceed 0.003 inch per inch of cylinder diameter. The liner may also need to be replaced if it is badly worn or out of round. When replacing piston rings, first fit them to the cylinder to check for proper end clearance. File the ends, if necessary, to make them fit. The side clearance of the rings should be such that the rings will fall easily into the piston grooves, which should be deep enough for the ring thickness. Ring splits should be staggered. After assembly of the piston, wire the rings tight with a soft copper wire, so that they will enter the bore easily. The wire can be removed through the valve ports after the ring has started into the cylinder bore.

When reassembling the air cylinders and heads, be sure they are all drawn down evenly, especially on multistage compressors where the heads contain cylinders for third and fourth stages. Otherwise, excess wear on the cylinders and pistons will result.

When a compressor piston has been replaced, the piston end clearance must be checked. This is done by inserting a lead wire through a valve port or indicator connection. Jack the compressor over. When the piston has moved to the end of its stroke, the lead will be flattened to the exact amount of clearance. The wire should be long enough to permit a reading near the center of the piston. These readings should also be taken after any adjustment or replacement of these bearings: main, crank, wrist pin, or crosshead. Methods of adjusting the clearances vary in accordance with compressor design; consult the manufacturer's technical manual for this adjustment.

LUBRICATION SYSTEM

Proper care of a compressor lubrication system includes the following procedures:

1. Keeping the oil at a normal level in the sump at all times, in order to maintain proper oil temperature.
2. Changing crankcase oil periodically, and at the same time cleaning and flushing the crankcase and cleaning the oil filter.
3. Maintaining proper lube oil pressure, by keeping the oil in good working order and adjusting the bypass relief valve.
4. Keeping the oil cooler free from leaks (since pressure on water side exceeds that of the oil), to prevent oil contamination and emulsification.

5. Occasionally replenishing transparent liquid (glycerine and water) in lubricator sight-feeds.

6. Properly adjusting the lubricator for the specified quantity of oil feed.

COOLING SYSTEM

Proper care of a compressor cooling system includes the following inspections and maintenance procedures:

1. Periodically inspecting the inter coolers and after coolers.
2. Removing collections of gummy oils or tarry substances from the cooler tubes by washing tube nests with a suitable solvent. See that they are thoroughly dry before reassembling.
3. Correcting any leakage in tube nests, to prevent leaks of water into the compressor while secured, or leaks of air into water side during operation.
4. Inspecting and cleaning cylinder water jackets periodically with a cleaning nozzle.

When FILLING THE COOLING WATER SYSTEM after the compressor has been drained, open the water inlet valve slightly to allow the water to rise slowly in the cooler shells and water jackets. Vent valves fitted to the water spaces should be opened to permit entrapped air to escape, and to remove any air pockets.

CONTROL DEVICES

Because of the great variety of REGULATING AND UNLOADING DEVICES employed on compressors, consult the manufacturer's technical manual for information regarding the adjustment of these devices on particular compressors.

If a control valve fails to work properly, it should be taken apart and cleaned. Some valves are fitted with a filter filled with a sponge or woolen yarn to prevent particles of dust or grit from being carried into the valve chamber, and to remove gummy deposits from oil used in compressor cylinders. When repacking, use only genuine wool. Cotton will pack and stop the air flow.

Relief valves, very important for safe compressor operation, should be set as specified by the manufacturer, test-lifted by hand each time the compressor is placed in operation, and periodically tested by raising the pressure in the system to which they are attached (to check the setting).

MISCELLANEOUS ADJUSTMENTS

Miscellaneous adjustments required from time to time on compressors include those pertaining to wrist pins, crosshead shoes, reduction gears, couplings, and V-belt drives. The manufacturer's technical manual will give specific information for the care, adjustment, and replacement of all fitted bearings. Refer to the manufactuere's tehcnical manual for detailed and specific information regarding when and how to make these adjustments.

WRIST PIN BUSHINGS are replaced when necessary, such as when maximum recommended tolerances have been exceeded. In making a replacement, be sure the oil hole in the bushing is properly lined up with the oil hole in the connecting rod. After being pressed into the rod, the new bushing must be reamed.

CROSSHEAD SHOES are provided with shim or wedge adjustment. Wear should be slight, but adjustment should be made when the travel of the piston rod causes a movement in the stuffing boxes.

Alignments of REDUCTION GEARS AND PINIONS should be checked periodically, especially on a new compressor. Misalignment may be caused later by settling, straining, or springing of foundations; pipe strains on turbine-driven compressors; bearing wear; or springing due to heat from a turbine.

FLEXIBLE COUPLINGS require very little maintenance when properly lined up. Some types require occasional lubrication to prevent excessive wear of springs or bushings. A noisy coupling is an indication that the bushing is worn and requires replacement.

V-BELT DRIVES require adjustment for belt tension. Belts generally stretch slightly during the first few months of use. A loose belt will slip on the motor pulley and cause undue heating and wear on the belt. A tight belt will overload the bearings. Belts should be protected against oil and excessive temperatures, to prevent rapid deterioration. V-belts are usually installed in sets of two or three. If a single belt is worn or deteriorated, then the complete set should

System, Subsystem, or Component	Reference Publications
Low-Pressure Compressed Air Plant	

Bureau Card Control No.					Maintenance Requirement	M.R. No.	Rate Req'd.	Man Hours	Related Maintenance
AP	ZZZFCH5	85	2398	W	1. Inspect oil level. 2. Run unit by power, check automatic starting, and stop. 3. Blow down receivers and separators.	W-1	MM3	0.2	None
AP	ZZZFCH5	75	5927	M	1. Lift relief valves by hand. 2. Sample and inspect lube oil.	M-1	MM3	0.3	None
AP	ZZZFCH5	75	2840	M	1. Clean the air cooler fins. 2. Clean the air filter.	M-2	MM3	0.5	None
AP	ZZZFCH5	75	5369	Q	1. Inspect "V" belts for wear or stretching.	Q-1	MM3	0.5	None
AP	ZZZFCH5	85	2841	Q	1. Sound and tighten foundation bolts. 2. Inspect the air receiver and piping for external corrosion. 3. Drain and clean the compressor crankcase. 4. Inspect and clean the suction and discharge valves.	Q-2	MM3	2.5	None
AP	ZZZFCH5	C5	4803	A	1. Test all parts of air system under full working pressure.	A-1	MM3	1.5	None
AP	ZZQFVA1	75	2843	C	1. Test relief valves for proper lifting pressure.	C-1	MM3	0.5	None
AP	ZZ2FRG7	75	7203	C	1. Inspect interior of air receivers.	C-2	MM3 FN	0.5 0.5	None
AP	ZZ2FRG 6	75	6542	C	1. Hydrostatically test air receiver.	C-3	MM3 FN	1.0 1.0	None
AP	ZZZFCH5	85	7082	C	1. Disassemble the compressor and inspect internal parts for wear.	C-4	MM2 MM3	12.0 12.0	Q-2

MAINTENANCE INDEX PAGE
OPNAV FORM 4700-3 (4-64)

BUREAU PAGE CONTROL NUMBER A-4/30-65

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Figure 15-10.—Planned maintenance for a low pressure air compressor.

be replaced to ensure that each belt will carry its share of the load.

PLANNED MAINTENANCE

The Maintenance Index Page (MIP) shown in figure 15-10 lists the planned maintenance for a low pressure air compressor, that is typical of the maintenance required on most air compressors. These maintenance requirements are in addition to those previously discussed under Care of Air Compressors.

SAFETY PRECAUTIONS

There are many hazards associated with the process of air compression. Serious explosions have occured in high pressure air systems because of a diesel effect. Ignition temperatures may result from rapid pressurization of a low pressure dead end portion of the piping system, malfunctioning of compressor aftercoolers, leaky or dirty valves, and many other causes. Every precaution must be taken to have only clean, dry air at the compressor inlet.

Air compressor accidents have also been causes by improper maintenance procedures such as disconnecting parts while they are under pressure, replacing parts with units designed for lower pressures, and installing stop valves or check valves in improper locations. Improper operating procedures have also caused air compressor accidents, with resulting serious injury to personnel and damage to equipment.

In order to minimize the hazards inherent in the process of compression and in the use of compressed air, all safety precautions outlined in the manufacturers' technical manual and in the Naval Ships Technical Manual must be strictly observed.

1. Explosions may be caused by dust laden air, presence of oil vapor in the compressor or receiver, and by leaky or dirty valves resulting in abnormal high temperatures.
2. Never use benzine, kerosene, or other light oils to clean compressor intake filters, cylinders, or air passages. These oils vaporize easily and will form a highly explosive mixture with the air under compression.
3. Secure a compressor immediately if it is observed that the temperature of the air discharged from any stage rises unduly or exceeds the maximum temperature recommended.
4. Never leave the compressor station after starting the compressor unless you are sure that the control, unloading, and governing devices are operating properly.
5. To prevent damage due to overheating, compressors must not be run at excessive speeds. Proper cooling water circulation must be maintained.
6. If the compressor is to remain idle for any length of time, and is in an exposed position in freezing weather, the compressor circulating water system should be thoroughly drained.
7. Before working on a compressor make sure that the compressor is secured and cannot start automatically or accidentally. The compressor should be blown down completely, all valves (including control or unloading valves) between the compressor and the receiver should be secured. Leave the pressure gages open at all times.
8. When cutting air into the whistle, siren, or piece of machinery, be sure the supply line to the equipment has been properly drained of moisture. When securing the supply of air to the affected equipment, be sure all drains are left open.
9. Prior to disconnecting any part of an air system be sure that it is not under pressure. Pressure gages should always be left open to the sections to which they are attached.

CHAPTER 16

ADDITIONAL AUXILIARY EQUIPMENT

There are a number of AUXILIARY UNITS OUTSIDE THE REGULAR ENGINEERING SPACES which you will be expected to know something about. This machinery includes the steering gear, anchor windlasses, deck winches, capstans, cranes, elevators, pumps, and miscellaneous remote controlled valves. You may or may not be responsible for the operation of this equipment, but you must know how to maintain the units in good operating condition. Most of this auxiliary equipment operates hydraulically.

It may be helpful for you at this point to review the chapter on hydraulic principles and machinery in Basic Machines, NAVPERS 10624-A, and Fluid Power, NAVPERS 16193-B.

Some pieces of the auxiliary machinery, such as anchor windlasses, are required to operate at variable speeds over a considerable range. In addition, there must be close control of speed between maximum and minimum limits. A common requirement of this auxiliary machinery is high starting torque and ability to accelerate to maximum speed quickly. To meet these requirements in modern Navy ships, the electrohydraulic drive has been adopted. Because some of the older ships are still being used, we will also discuss electromechanical machinery.

As a Machinist's Mate, you are also responsible for maintaining and repairing galley and laundry equipment, when required. This equipment is maintained in operating condition through the joint efforts of operating personnel and maintenance personnel. In general, the operator will keep the equipment clean, make minor adjustments related to the operation of the machine, and, in some installations, accomplish routine maintenance. When trouble occurs, the operator must determine whether electrical or mechanical equipment is involved. If mechanical equipment needs maintenance, it is the responsibility of the Machinist's Mate to make the necessary repairs, replacements, or adjustments. Therefore, a section dealing with the maintenance of galley and laundry equipment is included in this chapter.

Inasmuch as Machinist's Mates are required to handle one or all of the several compressed gases used aboard ship, you should have a general understanding of the characteristics and uses of these gases. Therefore, this chapter has a section dealing with industrial gases.

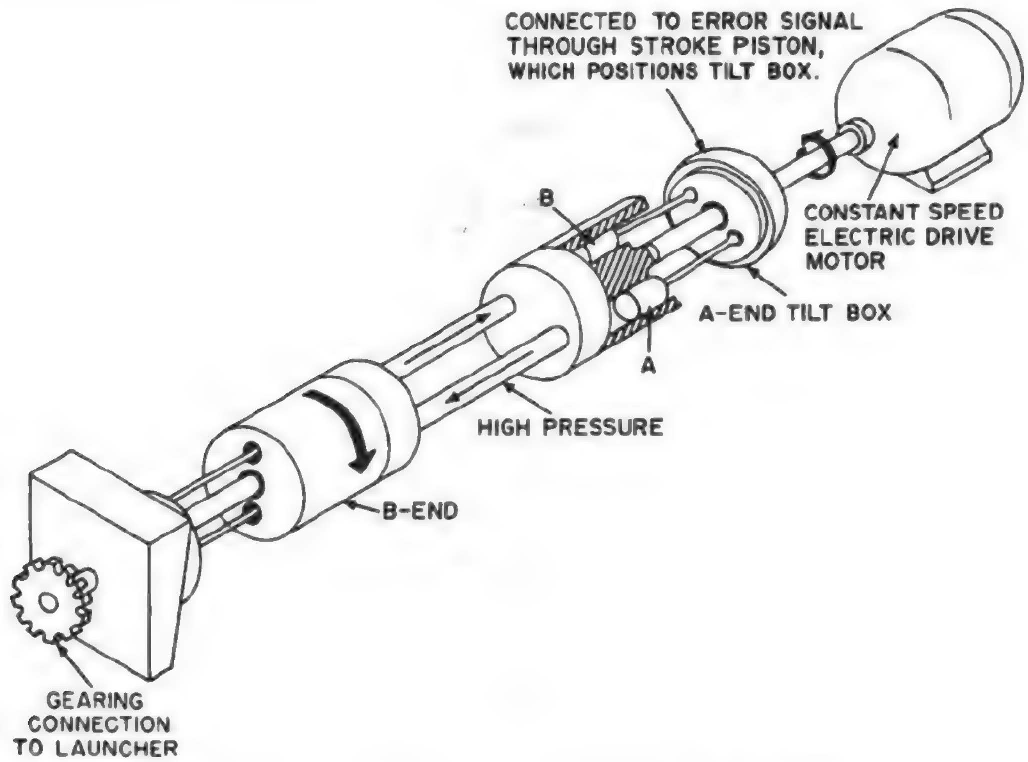
ELECTROHYDRAULIC SPEED GEAR

Rotary motion, transmitted by hydraulic equipment, is accomplished by use of a combination of electrically driven hydraulic pump (A-end) and a hydraulic motor (B-end). See figure 16-1. For a discussion of the operation of this pump (axial piston variable-stroke pump) refer back to chapter 5 of this training manual.

Since the B-end is already on stroke, it will be made to rotate by the hydraulic force of the oil acting on the pistons. Movement of the pistons' A-end is controlled by a tilt box in which the socket ring is mounted.

By moving the tilt box one way or another, and by the amount of angle at which the tilt box is placed, the length of piston movement is controlled. This in turn controls the amount of fluid flow. The A-end is always in motion, but with the tilt box in a neutral or vertical position no oil is pumped to the B-end. Any movement of the tilt box, regardless of how slight, causes pumping action to start, and therefore causes immediate action in the B-end.

When reciprocating motion is desired, such as in a steering gear, the B-end is replaced by a piston or ram. The force of the hydraulic fluid causes the movement of the piston or ram. The tilt box in the A-end can be controlled either locally (as on the anchor windlass) or by remote control (as on the steering gear).



83.81(83B)
Figure 16-1.—Operation of hydraulic transmission.

USES OF ELECTROHYDRAULIC SPEED GEAR

Hydraulic units are used for driving or controlling steering gears, windlasses, winches, capstans, airplane cranes, ammunition hoists, and distant control valves. This chapter contains information on hydraulic units with which Machinist's Mates are concerned.

ADVANTAGES OF ELECTROHYDRAULIC MACHINERY

The electrohydraulic type of drive very efficiently meets the operating requirements of modern naval machinery. Some of the major advantages of electrohydraulic machinery are that:

1. Tubing, which can readily transmit fluids around corners, is used to conduct the liquid which transmits the force.
2. Very little space is required for tubing.
3. It allows flexibility in location of components.
4. Operation at variable speeds is possible.
5. Close control of speeds from minimum to maximum limits is allowed.
6. It can be shifted from no load to full load rapidly without damage to machinery.
7. It accelerates quickly.
8. It has a high rate of efficiency.
9. It has a favorable power to weight ratio.

STEERING GEARS AND THEIR CONTROLS

The steering gear is the mechanism which transmits power from the steering engine to the rudder stock. The term is frequently used to include the driving engine and the transmitting mechanism.

The following two types of steering gear are found on naval ships: electrohydraulic and electromechanical.

ELECTROHYDRAULIC STEERING GEAR

Most steering gear installations on modern naval ships are of the electrohydraulic type, and use only the A-end of the previously described electrohydraulic speed gear. The development of the electrohydraulic type of steering gear was prompted primarily by the large momentary electrical power requirements for electromechanical steering gears—particularly for ships of large displacement and high speed. Also the elimination of d-c power from ships made switching and speed control of electric motors more difficult.

Types of Steering Gears

There are various types of electrohydraulic steering gear layouts in use, but their operating principles are about the same. Some ships have double hydraulic rams and cylinders mounted fore and aft; others have double-cylinder single rams mounted athwartships. Some systems use axial piston variable-stroke pumps; others use radial piston pumps.

Information on components of a hydraulic system is provided in Fluid Power, NAVPERS 16193-B.

How the Steering Gear Operates

Figure 16-2 shows a simple diagrammatic arrangement of a double-ram type electrohydraulic steering gear. Here the RUDDER YOKE is connected to two hydraulic PLUNGERS or RAMS, each ram is equipped with CYLINDERS at both ends. The pressure of the hydraulic fluid in the closed system is maintained by one of the two rotary, positive displacement, VARIABLE-STROKE PUMPS. The rate of fluid delivery is ragulated by the angle of the TILTING BOX in the hydraulic pump, which is in turn controlled either electrically or hydraulically from the steering wheel on deck. The CONTROL SHAFT and gearing are indicated in figure 16-2.

Note that the forward port and after starboard cylinders are interconnected, and that the same is true of the forward starboard and the after port cylinders. A double-acting RELIEF VALVE serves to bypass the fluid from the supply (or

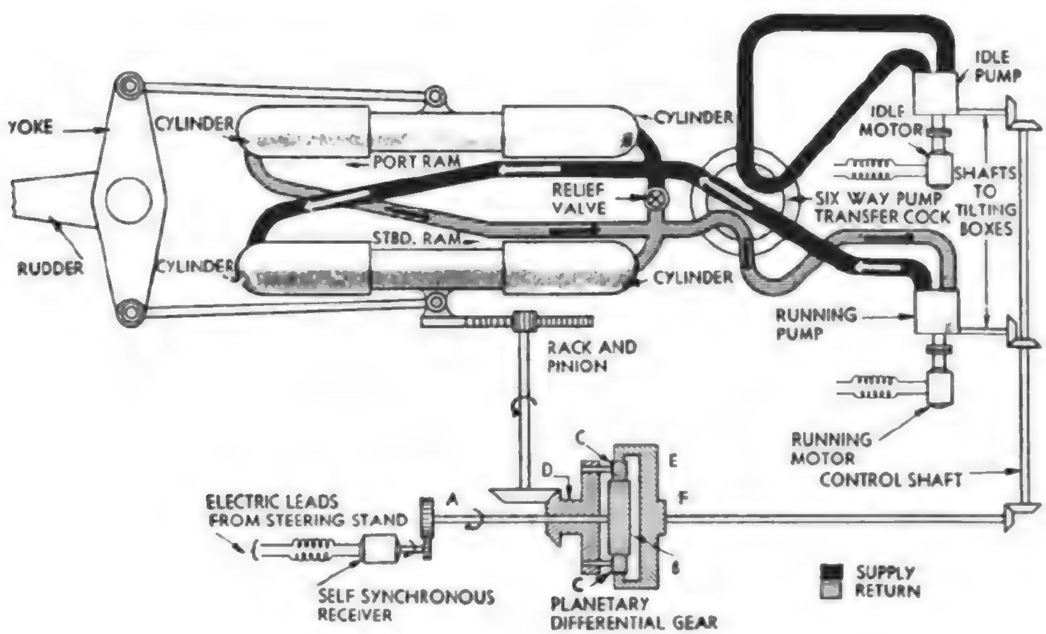


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Figure 16-2.—Simple diagrammatic arrangement of a double-ram electrohydraulic steering gear.

the discharge) to the return (or the suction) line, thus relieving the piping from excessive strain, should an unusual resistance to the rudder (caused by wave action or by jamming) result in abnormal oil pressures. The motors run at constant speed. Examples of steering gear operation follow.

Starting with a neutral position of the tilting box and no flow of oil, suppose the STEERING WHEEL is turned to starboard. Turning the wheel on the bridge causes an electric signal to be transmitted to the synchronous receiver in the steering gear room. The SYNCHRONOUS RECEIVER will then turn correspondingly (counterclockwise in fig. 16-2, as viewed from the left). Shaft A is turned clockwise, carrying gear B with it. The gears C, meshing with gear B and internal gear teeth on E, turn counterclockwise. Then E turns counterclockwise and turns the CONTROL SHAFT, which operates the TILTING BOXES on the PUMPS. A quantity of oil now flows to the forward port and after starboard cylinders, the rams move as indicated in figure 16-2, the rudder is thereby caused to move to the right, and an equal portion of oil is returned to the pumps from the opposite cylinders.

When the steering wheel and synchronous receiver stop moving, the starboard ram, in moving forward, operates the RACK AND PINION and turns gear D clockwise. Gear B and shaft A are held by the now motionless synchronous receiver, and gear C and casing E turn clockwise, thus returning the tilting boxes to the neutral position and stopping the flow of oil. The PLANETARY DIFFERENTIAL GEAR thereby, operates as a followup mechanism. If the steering wheel is turned to port, the actions described are the opposite in direction.

In actual installations, two sets of synchronous receivers, two sets of electric motors and pumps, are provided for reliability and flexibility. The SIX-WAY PLUG COCK makes it possible to transfer quickly from the operating pumps to the standby pump.

The single-ram type of electrohydraulic steering gear, illustrated in figure 16-3, operates on the same principle as the double-ram type. The only difference is that there is but one ram, with port and starboard cylinders, mounted athwartship. As the port plunger is forced to move by the pressure of oil against it, the starboard plunger moves correspondingly and forces the same amount of oil out of the starboard cylinder.

ELECTROMECHANICAL STEERING GEAR

Electric motors were first introduced as prime movers of steering gears on combat ships to serve in case of failure of the steam steering engines. Later on, however, they were used as the primary source of power, with steam as a reserve. This type of steering equipment may be found on naval auxiliary ships which have been converted from maritime type ships.

Principles of Operation

The principles of operation are practically the same for all designs of electromechanical steering gear. Any differences that exist are mainly in the manner in which the driving motor is connected to the rudder stock, and the method by which the motor is controlled. The electric motor drives a right-and-left screw or worm gear and quadrant, or it may drive a winch drum connected to a quadrant on the rudder stock with wire rope. The steering motor control may be either followup or non-followup. In the non-followup type, the motor is controlled by a master controller at the steering station and continues to turn as long as the control is held over unless power is interrupted by a limit switch.

When the master controller is brought to neutral, dynamic braking action takes place to slow down the motor; the motor is finally brought to rest and held by a magnetic brake. The followup type of control usually uses a roller and ring type contact in the steering engine stand. The rollers are geared to the helm and rotating the wheel brings a roller in contact with a contact ring. The ring is connected to the motor control panel and when the circuit is closed, the motor turns in the proper direction. When the ring has rotated to the required position, the electrical circuit is broken and the motor stops.

Most wire rope and chain drive steering gears use a followup control system. The followup motion is transmitted from the steering gear to the steering stand by means of shafting, bevel gears, and flexible couplings.

In most electromechanical installations, the shafting connecting the steering engine to the wheel is utilized not only to provide followup control to the steering stand, but also to provide a means for steering by hand from the pilot house if power is lost.

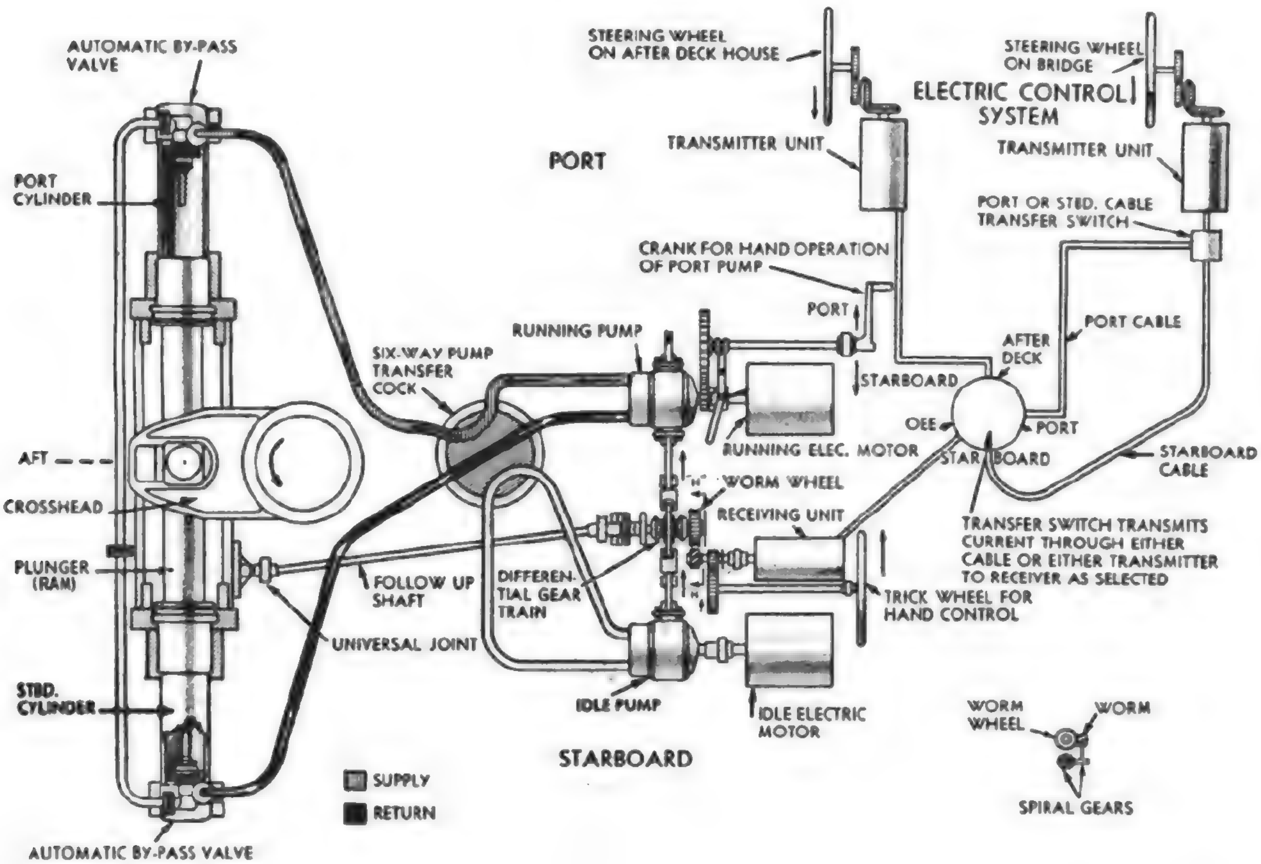

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Figure 16-3.—Diagrammatic arrangement of a single-ram electrohydraulic steering gear.

The electromechanical steering gear should be maintained in accordance with the Planned Maintenance System requirements or instructions in the manufacturer's technical manual.

CONTROL OF STEERING GEARS

Control of the steering gear from the steering wheel on the bridge may be accomplished by any of the following remote control systems, although most modern naval ships use the first one:

1. ELECTRICALLY, by means of an alternating current synchronous transmission system.
2. HYDRAULICALLY, by means of a hydraulic telemotor system.
3. ELECTRICALLY, by means of a direct-current pilot motor and its controller.
4. MECHANICALLY, by means of a shafting or wire rope from the steering station.

Alternating-Current Synchronous Transmission

The alternating current synchronous transmission type of remote control consists of receiving and transmitting units which are similar to small motors; there are connected to the same alternating-current supply. When the transmitter rotor is turned, the receiver motor turns at the same speed and in the same direction.

The transmitters are located in steering stands, at remote control stations and are mechanically connected through gearing to the wheels. A transmitter at one of the remote stations is electrically connected to a receiver in the steering room. The receiver is connected

to the control shaft of the variable displacement hydraulic pump through a differential. Where more than one remote steering station is provided, a switch is provided for selecting the desired control station. Indicating lights are provided on the steering stands and at the selector switch to indicate the selected circuit and that power is available.

Hydraulic Telemotor Control

The hydraulic telemotor type of remote control (fig. 16-4) is found on many Navy auxiliary ships that are equipped with electrohydraulic steering engines. The system (parts A and C of fig. 16-4) consists of a steering console (hydraulic transmitter) in the pilot house; a hydraulic receiver in the steering gear compartment, and connecting hydraulic tubing. In addition, there is an electric cable which connects the helm angle transmitter on the receiver housing with the helm angle indicator on the steering console.

A hydraulic transmitter is located inside the steering console and under the steering wheel. The hydraulic transmitter components consist of a pump, hydraulic tubing, two relief valves, two check valves, a replenishing tank, and a bypass valve. The remotely located receiver is a hydraulic plunger-type unit with two cylinders—one on each end of the receiver housing—in axial alignment. A double-acting plunger operates in the cylinders. On the middle portion of this plunger a crosshead is connected for mechanical linkage to the steering gear control mechanism.

The direction of the hydraulic fluid movement depends upon the direction of rotation of the steering wheel. Rotation of the steering wheel actuates bevel and spur gears which in turn operate a reversible, hydraulic, axial piston type pump. The operating principles of this pump are similar to those of the axial piston variable-stroke pump.

In the reversible axial piston pump, however, the socket ring is set permanently at a fixed angle so that the pistons are always on stroke. When the pump shaft and cylinder barrel are rotated by means of the steering wheel, the pistons draw fluid in from one hydraulic fluid line and discharge it to the other hydraulic fluid line. Reversing the rotation of the steering wheel reverses the direction of fluid flow through the pump. The pump has external check valves and piping for replenishing the hydraulic system from the tank. Relief valves and a bypass valve (part B of fig. 16-4) are also included, as well as vents for purging the system.

When the hydraulic pump shaft is rotated in one direction, the fluid output is discharged from one side of the pump to one of the receiver cylinders. In the other cylinder, hydraulic fluid is displaced to the hydraulic pump. Thus the hydraulic fluid under pressure moves the receiver plungers and produces a linear movement of the crosshead. This motion is, in turn, transmitted to the connected steering gear control mechanism. Travel of the crosshead and plungers is limited by adjustable stops on the receiver housing. In part C of figure 16-4, the solid arrows show direction of action for right rudder while the broken arrows show the flow of hydraulic fluid for right rudder.

Air cocks and filling or charging connections are provided on the receiver cylinders for venting, filling, or purging the hydraulic system.

FILLING THE TELEMOTOR SYSTEM from the charging tank is done by opening the air cocks at the forward telemotor and starting the charging pump. After the oil has appeared at the air cocks, the pumping is continued until the oil is free of bubbles. The air cocks are then closed and the oil allowed to fill the replenishing tank. While the pump is still operating, the valve leading to the replenishing tank is closed and the system is subjected to a slight pressure.

The effective operation of the telemotor system depends upon the PURGING OF ALL ENTRAINED AIR and the elimination of leaks. Purging the system of air, under normal operating conditions, is done by opening the valve leading from the replenishing tank, and the air cocks at the forward telemotor. Because the replenishing tank is located above the highest point of the telemotor system, the air is forced out of the air cocks by the gravity flow of oil. The cocks are closed when the oil flows smoothly without bubbles.

To detect and eliminate leaks in the system, the valves and joints should be inspected frequently. To correct a leaky piston in the internally packed telemotor, see that the leathers are in good condition, and that the springs (if used) keep the leather in contact with the inside wall of the telemotor cylinders. To stop leaks in the externally packed telemotor, tighten the glands just enough to cause the packing to be compressed about the rams, until the leak is stopped.

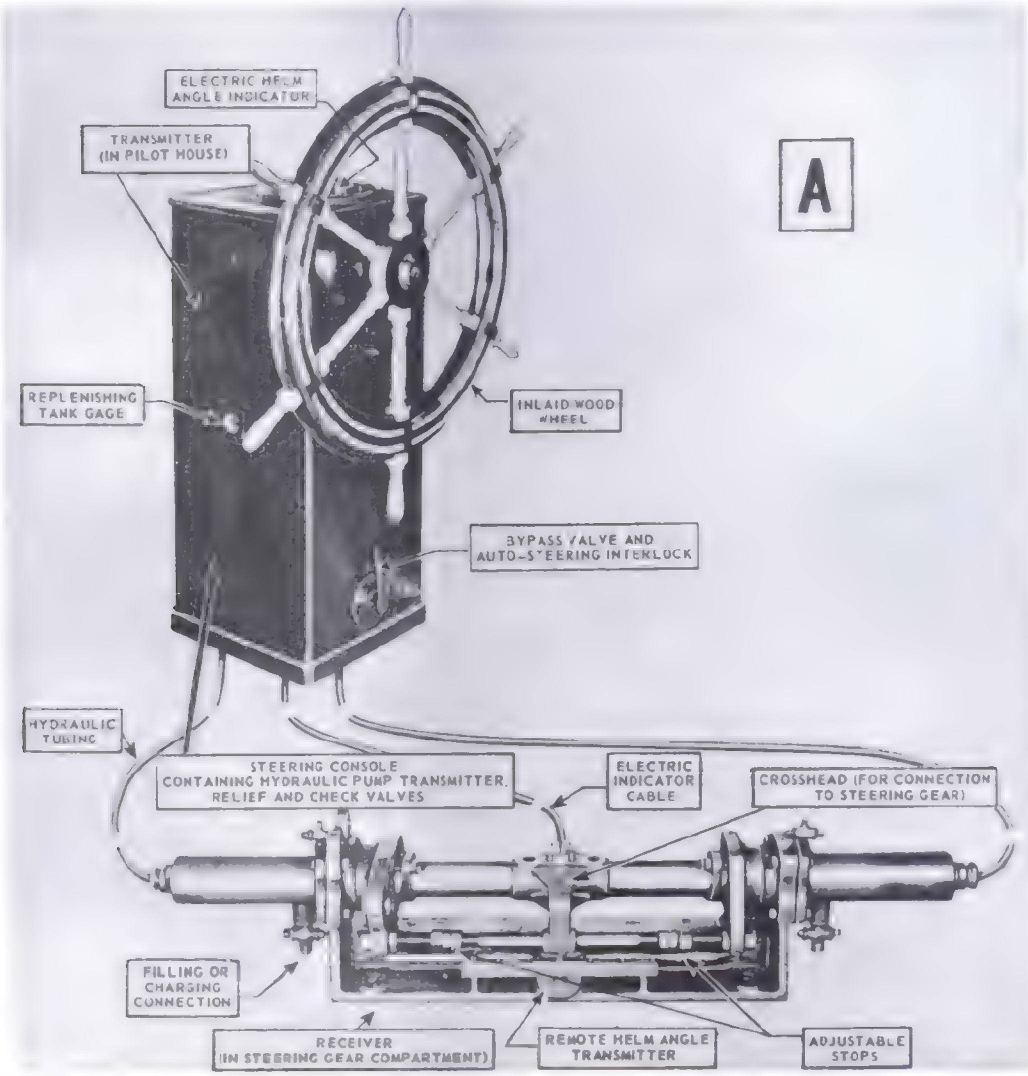

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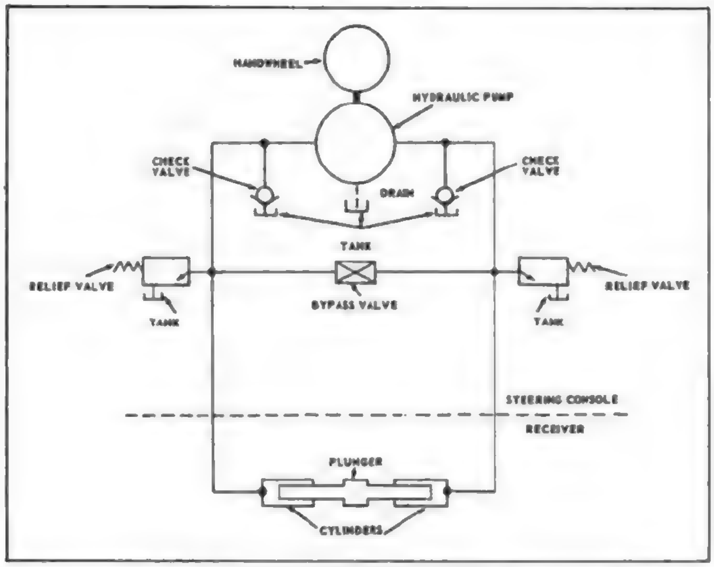
Figure 16-4.—Hydraulic telemotor control. A. Telemotor components.

The HYDRAULIC FLUID CHARACTERISTICS are especially important when the telemotor system is exposed to low ambient temperatures. Under such conditions, a high grade mineral oil having a cold pour point of -24° F to -40° F should be used. Where low temperatures are not involved or where special oil with the designated cold pour point cannot be readily obtained, the symbol 2075H oil may be used satisfactorily. The oil should have a low rate of expansion and be sufficiently viscous at 150° F to remain a good hydraulic fluid.

When FILLING THE CHARGING TANK with hydraulic fluid, strain the oil into the tank through a funnel which has in it a fine mesh screen. This prevents the entry of foreign matter and at the same time prevents the entry of air bubbles into the hydraulic system. The oil should never be allowed to become contaminated with water.

Direct-Current Pilot Motor Control

The direct-current pilot motor type of remote control is used with some early electrohydraulic steering gears. It consists of a small, reversible direct-current motor, which is connected, through



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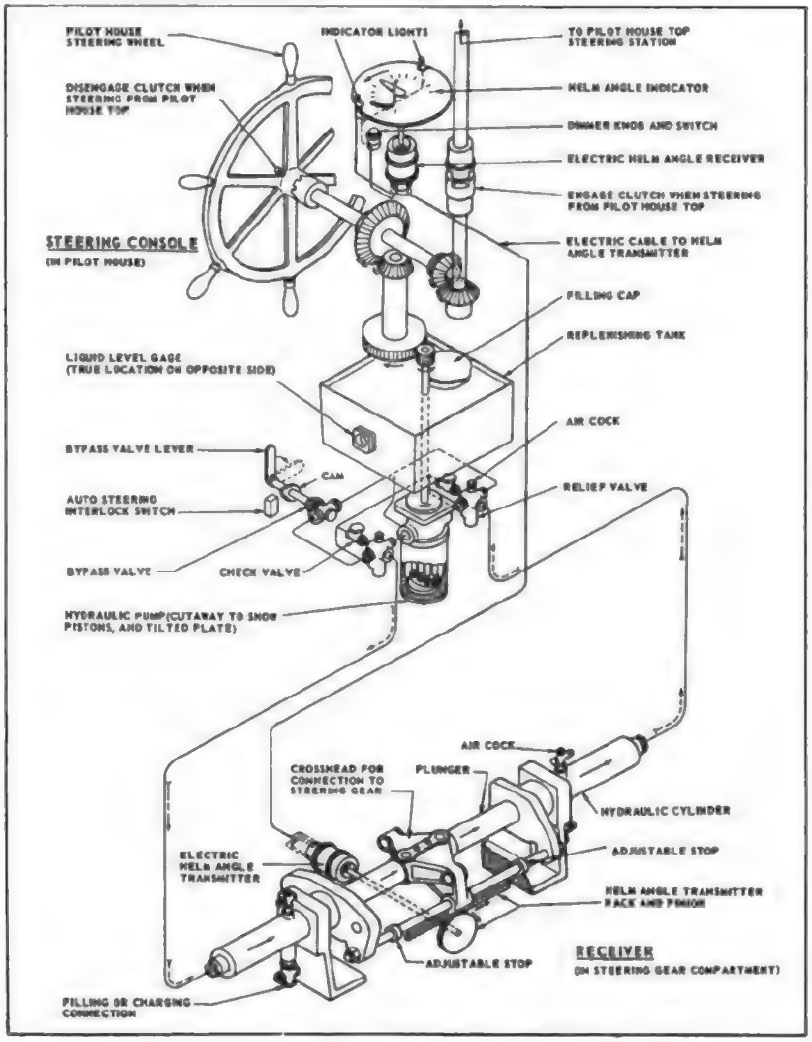

C

Figure 16-4.—Hydraulic telemotor control—Continued. B. Hydraulic circuit diagram. C. Schematic diagram of telemotor c[illegible]

a differential gear, to the control shaft of a variable-stroke pump. The pilot motor is controlled by means of a magnetic control panel located next to the motor, and with a master controller located at the steering wheel. (The motor has a magnetic brake which stops and holds the motor when the master controller is returned to the neutral position.)

Auxiliary Hand Operation

Auxiliary hand gear is provided for most ships that have electrohydraulic steering gears. This auxiliary hand gear usually consists of a hand-operated hydraulic pump supplemented by chain hoists.

The hydraulic emergency steering system consist of a relief valve, shuttle valve, hand-operated dual hydraulic pump, associated piping, valves and fittings. The piping from the emergency pump to the main hydraulic system is arranged so that the high-pressure stop valves may be closed to prevent leakage through the main hydraulic units from the pressure developed by the hand pumps. The emergency pump is usually connected to the main hydraulic system, permitting the use of all four ram cylinders. If the emergency pump is not connected in this manner, it is necessary to reduce the speed of the ship in order to limit the ram pressure to that permitted by the pump design. Since it is necessary to block off the emergency system under normal steering gear operation, the emergency lines are generally connected to the drain valves; this eliminates the necessity of additional high pressure valves.

As the emergency steering system, described in this section, depends upon an intact hydraulic system for operation, rudder positioning equipment to permit steering with the propellers (after all other means of steering have been rendered inoperable) is also furnished. This equipment consists of some type of mechanical device for moving the rudder with the ship dead in the water.

Steering Engineroom Watch

As a Machinist's Mate, you may be required to stand watch in the steering engineroom. The duties of the steering engineroom watch include operation, care, and emergency repair of the machinery in your charge. Operating instructions and system diagrams are posted in the steering gear room. The diagrams describe the various methods of operating the steering gear under normal as well as emergency conditions. The diagrams show the position of the valves for setting the gear for each method of operation.

During your watch in the steering engineroom make sure that the standby equipment is ready for instant use in case of an emergency. Inspect the steering gear thoroughly. The unit in operation should be checked by feeling the various parts. Any part that feels "HOT" to the bare hand should be reported to the officer of the deck (OOD) on the bridge and to the officer of the watch in main engine control. Investigate for binding, overloading, and lack of lubrication. Listen for new or unusual sounds which indicate loose parts or wear. Bleed all air out of the system. Check for leaks in the lines and fittings. Piping leaks usually occur following unusual strain (rough seas). Most leaks can be corrected by tightening the flange bolts. Small leaks at ram packing glands are not objectionable since the small flow of hydraulic fluid provides lubrication. Always maintain sufficient fluid in the tanks. Check and ensure that all grease fittings and surfaces requiring lubrication are lubricated in accordance with the instructions on the lubrication chart.

All applicable safety precautions should be observed. Keep oil off the deck. Extreme caution should be exercised when working in the confined spaces around the rams and actuating gear. All clothing should be free of loose ends that might catch in the machinery.

Steering Casualty

Steering is normally controlled in the pilot house by the helmsman, who receives his orders from the commanding officer via the officer of the deck. If steering control is lost from the pilot house, control must be shifted to steering aft using emergency procedures. Shifting of control may be necessitated by damage to the telemotor system or remote control apparatus, or as a routine underway training measure to test the preparedness and efficiency of the steering engineroom watch party.

In general, this is what would take place when shifting from normal steering control to steering aft in event of a steering casualty. The pilot house watch would sound the steering alarm located in steering aft. At the same moment "STEERING CASUALTY—STEERING CASUALTY" would be sounded over the general

announcing system and the JV circuit. The steering engineroom watch would immediately, and without further orders, take control of the trick wheel. They would match the trick wheel to the actual rudder position. If necessary, the steering engineroom watch party would shift to the standby unit. They would report to the OOD as soon as steering aft had steering control and would steer as directed by the OOD. You, as a Machinist's Mate, would determine the nature and extent of damage or casualty, and report to the OOD, and to the officer of the watch in the main engine control. As soon as you have repaired the casualty, report it to the OOD, and to the officer of the watch in the main engine control. Upon being ordered to shift control back to the pilot house, you would bring the rudder amidships with the trick wheel, shift control to the pilot house, and report to the OOD that the pilot house has control.

MAINTENANCE OF ELECTROHYDRAULIC STEERING GEARS

The maintenance required for most electrohydraulic steering gears is shown on the Planned Maintenance Index Page, figure 16-5. In addition to this maintenance, it is important that the exposed parts of the steering gear rams be protected against water and damage from rolling or falling objects. Cover them with a thin film of rust-preventive compound or a heavy oil. To protect the exposed parts from rolling objects, place a guard over the parts, and keep the steering gear compartment clear of loose gear at all times.

WEIGHT-HANDLING EQUIPMENT

In order to qualify for advancement in rating, you must be familiar with the construction, operation, and maintenance of anchor windlasses, cranes, and winches. The discussion of such machinery and other weight-handling equipment, such as capstans and elevators, which follows, is supplementary to that given in Fireman, NAVPERS 10520-D.

ANCHOR WINDLASSES

In a typical electrohydraulic mechanism (illustrated in Fireman, NAVPERS 10520-D), there is one constant speed electric motor which drives two variable-stroke pumps through a coupling and reduction gear. Other installations include two motors, one for driving each of the pumps. Each pump normally drives one wildcat, though (with the use of 3-way plug cock type valves) either pump may drive either of the two wildcats. The hydraulic motors drive the wildcat shafts by means of multiple spur gearing and a locking head. The locking head permits disconnecting of the wildcat shaft thus permitting free operation of the wildcat as when dropping anchor.

Each windlass pump is controlled either from the weather deck or locally with handwheels on shafting leading to the pump control. The hydraulic system will require your attention. Make certain that the hydraulic system is always serviced with the specified type of clean oil.

The types of windlasses which a Machinist's Mate will probably have to maintain are the electric, electrohydraulic, and the hand-driven windlasses. Hand-driven windlasses are only used on small ships where the weight of the anchor gear is such that it can be handled without excessive effort by operating personnel.

In maintaining a hand windlass, the major factor is to keep the linkage, friction shoes, locking head, and brake in proper adjustment and in satisfactory operating condition at all times. In maintaining an electrohydraulic windlass, your principal concern will be the hydraulic system. Since hydraulic systems are basically the same, the information given under "Maintenance of Hydraulic Systems," later in the chapter, is applicable to steering gear, windlasses, winches, cranes, and elevators.

Even though used intermittently and only for relatively short periods of time, a windlass must be capable of handling the required load under extremely severe conditions. To prevent deterioration and to provide dependable operation wherever required, maintenance and adjustment must be continued during the periods when the machinery is not in use.

Windlass brakes must be maintained in satisfactory condition if they are to perform their function properly. Because of wear and compression of brake linings, the clearance between the brake drum and band will increase after a windlass has been in operation. Brake linings and clearances should be inspected frequently. Means of adjustment are provided on all windlass brakes. Adjustments should be made in accordance with the manufacturer's instructions.

System, Subsystem, or Component	Reference Publications
Steering Gear	

Bureau Card Control No.					Maintenance Requirement	M.R. No.	Rate Req'd.	Man Hours	Related Maintenance
AU	ZZZESRO	75	4065	W	1. Inspect all pins, couplings, and shafts. 2. Inspect agreement of helm angle indicator with mechanical rudder indicators. 3. Inspect ram packing glands for correct tightness. 4. Inspect system for excessive oil leaks.	W-1	MM3 FN	0.5 0.5	None
AU	ZZZESRO	65	A627	W	1. Lubricate ram room machinery. 2. Lubricate pump room machinery. 3. Inspect oil levels.	W-2	MM3	1.0	None
AU	ZZZESRO	25	2383	M	1. Inspect rudder stock packing. 2. Clean packing gland.	M-1	FN	0.5	None
AU	ZZZESRO	65	A628	M	1. Lubricate pump room machinery.	M-2	MM3	0.5	None
AU	ZZZESRO	72	6669	Q	1. Sound and tighten foundation bolts.	Q-1	FN	0.6	None
AU	ZZZESRO	45	9347	Q	1. Drain hydraulic oil filter on fill and drain pump.	Q-2	FN	0.2	None
AU	ZZZESRO	45	8150	Q	1. Provide hydraulic oil sample for chemical analysis.	Q-3	FN	0.1	None
AU	ZZZESRF	65	A629	Q	1. Inspect oil level and lubricate emergency steering gear. 2. Test operate unit.	Q-4	MM2 FN	0.5 0.5	None
AU	ZZ1ECW4	84	4915	S	1. Lubricate flexible couplings.	S-1	MM3	0.8	None
AU	ZZZESRO	65	A630	S	1. Lubricate follow-up gears.	S-2	FN	0.1	None
AU	ZZZESRO	65	A631	S	1. Filter oil in hydraulic system.	S-3	MM3 FN	3.0 3.0	Q-2
AU	ZZZESRO	25	7756	A	1. Renew oil in speed reducers.	A-1	MM3	1.0	None
AU	ZZZESRF	85	6368	A	1. Inspect motor brake and lubricate linkage.	A-2	MM3	0.3	None
AU	ZZZESRO	65	4919	A	1. Conduct operational test of steering gear.	A-3	MM1	0.3	None
					(Page 1 of 2)				

MAINTENANCE INDEX PAGE
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98.171

Figure 16-5.—Planned maintenance Index Page, steering gear.

Lubrication instructions furnished by the manufacturer should be followed carefully. If a windlass has been idle for some time, lubrication of the equipment should be accomplished before operation is attempted. After a windlass has been used, the equipment should be lubricated to protect funished surfaces from corrosion, and to prevent freezing of adjacent parts.

The hydraulic transmissions of electrohydraulic windlasses and other auxiliaries are manufactured with close tolerances between moving and stationary parts. If these tolerances are to be maintained and unnecessary wear prevented, every possible precaution must be taken to prevent the entry of dirt and other abrasive material. When the system is replenished or refilled, only clean oil should be used and the oil should be strained as it is poured into the tank. If a hydraulic transmission has been disassembled, all parts should be thoroughly cleaned before reassembly. Before piping or valves are installed, their interiors should be cleaned to remove any scale, sand, or other foreign matter.

WINCHES AND CAPSTANS

Winches are used for heaving in on mooring lines, hoisting boats, topping lifts on jumbo booms of large auxiliary ships, and for handling cargo. Power for operating shipboard winches is usually furnished by steam or electricity. Where delicate control and high acceleration without jerking are required, such as for handling aircraft, electrohydraulic winches are usually installed. Most modern auxiliary ships are equipped with either electrohydraulic or electric winches, while the other auxiliary ships are equipped with either steam or electric winches.

Cargo Winches

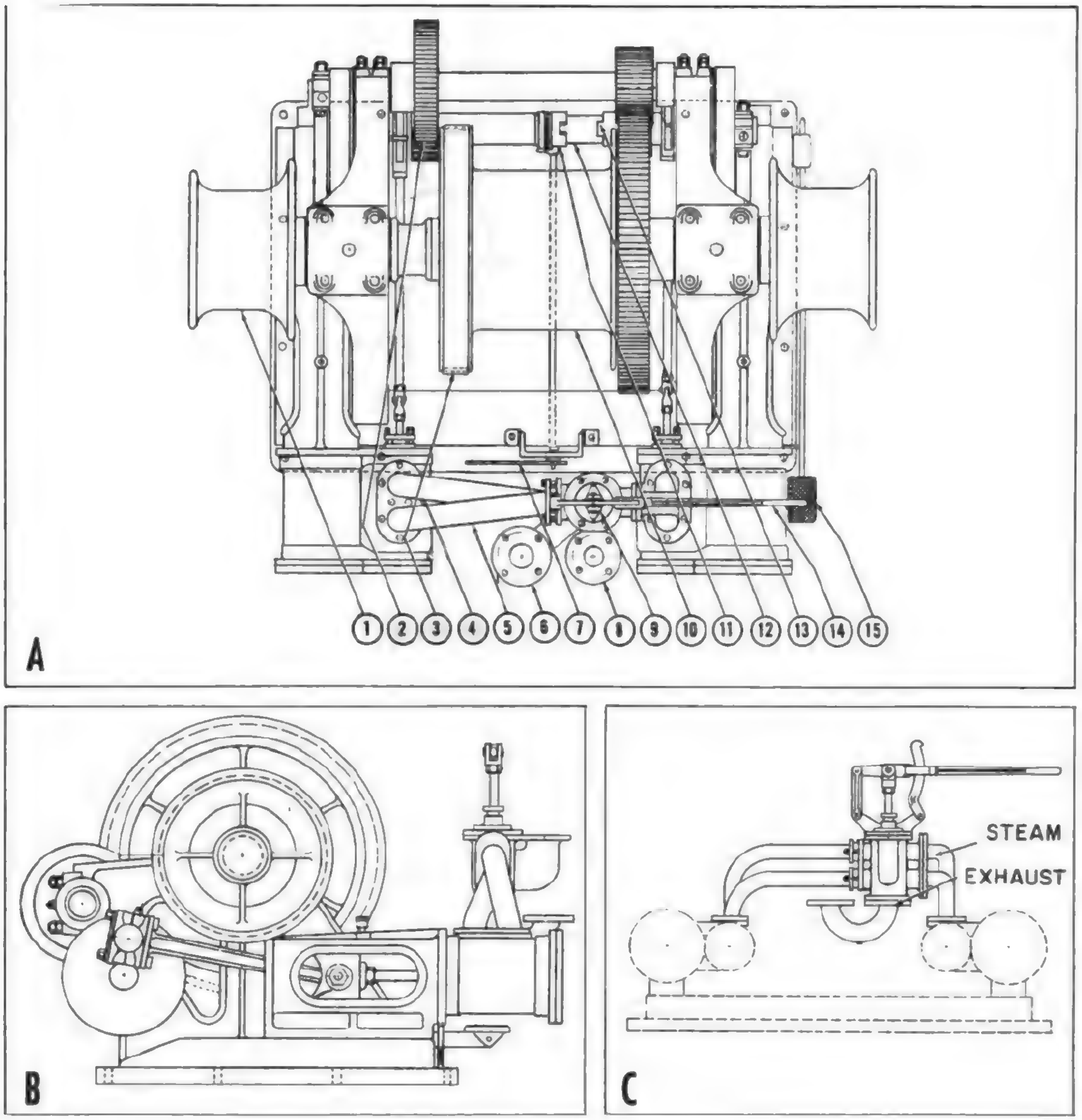
Among the various types of winches for general cargo handling are: double-drum, double-gypsy, and single-drum single-gypsy units. Four-drum two-gypsy machines are generally used for mine sweeping.

STEAM WINCHES.—The steam-operated deck winch (fig. 16-6) is driven by a two-cylinder, single expansion, double-acting reciprocating engine. The drive is by means of a train of spur gears in which a gear shift is provided to give two drive speeds.

Illustrated in figure 16-6 (part A) is a plan view of a winch with two gypsy heads (1), one mounted at each end of the main drive shaft. The speed and direction of rotation of the engine is controlled by a hand lever (14). Steam is admitted through the steam line connections (6) and (8). With the winch in "compound gear", the drum turns to lift a load when the hand lever (14) is raised. With the lever in this position, a spool-type valve passes steam from the reverse valve (9) through the two top horizontal pipelines (5) to the cylinders where it drives the engine. (Also see parts B and C of fig. 16-6.) The two lower pipes (4) are exhaust lines. When the lever is lowered below the horizontal position, the direction of steam flow is reversed in these pipes and the engine turns in the opposite direction, thus lowering the load. Some levers are provided with an automatic latch for holding them in the horizontal, or neutral position. For all other positions, the controls must be in the hands of the winch operator who must hold the lever in position for the desired speed.

A spool-type steam valve slides back and forth, opening and closing the ports for the flow of steam to or from the cylinders. The reciprocating motion of the steam valve is imparted to it by a rod moving through a stuffing box and connected to the eccentric on the main shaft.

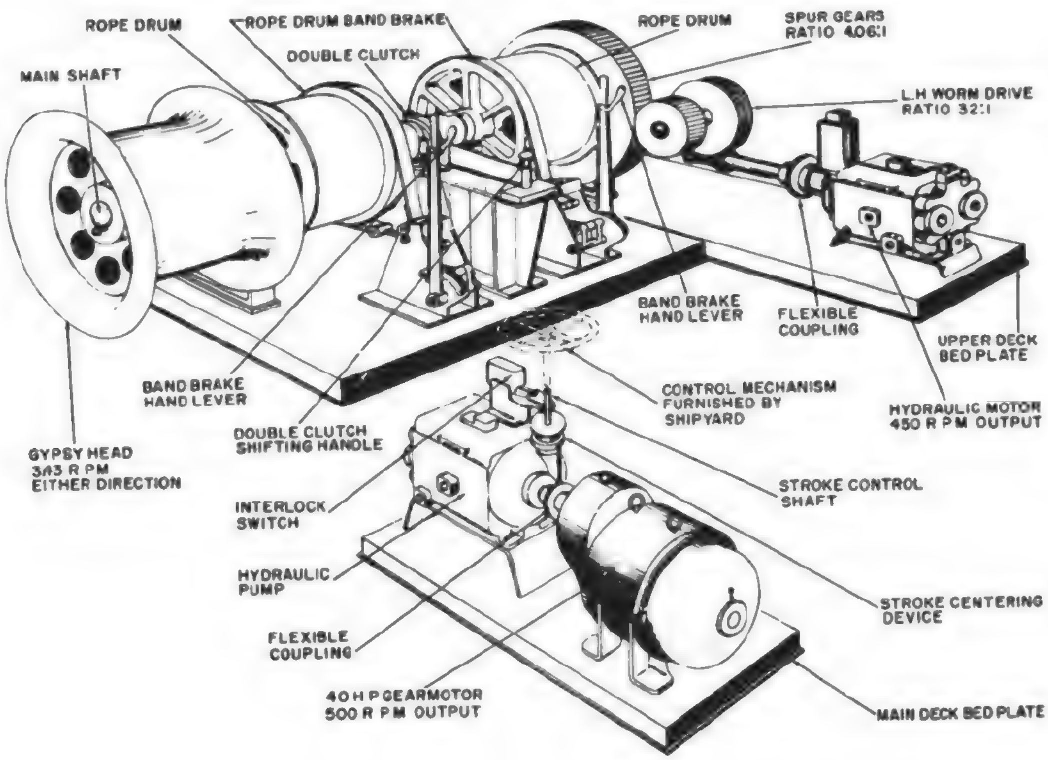
With the winch in "single gear" the direction of rotation is reversed and a load is raised by lowering the lever. The clutch mechanism consists of a sleeve (11) which is keyed to the crankshaft (12) and provided with a shifter yoke which is operated by a lever (7) located near the reverse valve (9). (See part C of fig. 16-6.) When this lever is thrown to the left (the position shown in part A of figure 16-6), the pinion which is integral with it, is engaged with the gear (2) on the intermediate shaft. This is the "compound gear" position and gives a slower-drum speed with an increase in available line pull. When the shifter lever (7) is thrown to the right, the driving sleeve is shifted to the right. This disengages the pinion from the intermediate shaft gear (2) and engages the square jaw clutch (13) and pinion which is always in mesh with the main drive gear. This gives a direct drive from the crankshaft to the main shaft, and is called the single gear position. The single gear position gives a higher drum speed for a given engine speed, but with a decrease in the available line pull.



47.144
Figure 16-6.—Steam-operated winch. A. Plan view. B. Side view. C. Reversing throttle valve.

The "neutral" position is obtained by placing the shifter lever (7) in the vertical position, leaving no connection between the driving sleeve (11) and either pinion. The shifter lever can be latched in any of the three described positions. Care should be taken to latch the lever in the desired position before the winch is operated.

When the winch is under heavy load, there is a high pressure between clutch faces, or gear teeth. This makes it impossible to shift the sleeve and change the gear ratio. To make



47.145
Figure 16-7.—Electrohydraulic winch units.

a change, it is necessary to remove the load from the winch and then turn the engine over very slowly while making the shift.

With the engine running in a given direction, the shifting from compound gear to single gear, or vice versa, reverses the direction of drum rotation. The design of the winch is such that lowering the load by lowering the hand lever (14), applies for heavy loads (compound gear), while the reverse, lowering the load by raising the lever (single gear) applies for higher speeds where heavy loads are not encountered.

The winch is provided with a gypsy head (1) at each end of the main drive shaft. Being keyed to the shaft, the gypsies are turned with the hoisting drum. The drum (10) is provided with a standard type of band brake (3) with a foot-operated control and ratchet lock. The locking device is controlled by springing the foot pedal (15) laterally. The brake band is secured to the winch bed plate in such a manner that the brakes may be conveniently taken up to compensate for wear.

ELECTROHYDRAULIC WINCHES.—Electrohydraulic winches (fig. 16-7) are always drum type. They are usually installed on ships with alternating current and where a wide range of speed, close control, and smooth acceleration are required, as in cargo handling. The drive equipment is like most hydraulic systems; a constant speed electric motor drives the (A-end) variable-stroke hydraulic pump which is connected to the (B-end) hydraulic motor, by suitable piping. The drum shaft is driven by the hydraulic motor through reduction gearing.

Winches normally have one horizontally mounted drum and one or two gypsy heads. If only one gypsy is required, it may be easily removed from or assembled on either end of the drum shaft. Gypsy heads are keyed to the drum shaft and rotate whenever the winch is in operation. Drums are not keyed to the shaft. When a drum is to be used, it is connected to the shaft by a clutch.

Capstans

The terms "capstans" and "winches" should not be confused. The primary differences between a winch and a capstan is that a winch has a

horizontal shaft and a capstan has a vertical shaft. The type of capstan installed aboard ship depends on the load requirements and type of power available. In general, a capstan consists of a single head mounted on a VERTICAL shaft, reduction gearing, and a power source. The types, classified according to power source, are electric and steam.

ELECTRIC CAPSTANS.—Electric capstans are usually of the reversible type and develop the same speed and power in either direction. Capstans driven by alternating-current motors have two speeds, full speed and one-half speed. Capstans driven by direct-current motors usually have from three to five speeds in either direction of rotation.

STEAM CAPSTANS.—Steam capstans were formerly used extensively on Navy ships, but they are now used only occasionally where the electric power is insufficient.

Steam capstans are driven by twin cylinder, reciprocating, reversible steam engines. A hand-operated control valve reverses and controls the speed of the capstan. Steam-driven capstans generally do not operate on full boiler pressure, usually a reducing valve is used to reduce the steam supply between 100 psi and 135 psi.

Maintenance of Winches and Capstans

In several respects, the maintenance of a winch or a capstan is similar to that of a windlass. Where band brakes are used on the drums, the friction linings should be inspected regularly and replaced when necessary. Steps should be taken to prevent oil or grease from accumulating on the brake drums. The operation of brake-actuating mechanisms, latches, and pawls should be checked periodically.

Winch drums driven by friction clutches should be inspected frequently to determine if deterioration has occurred in the friction material, or if oil and grease are preventing proper operation. The sliding parts of positive clutches must be properly lubricated, and the locking device on the shifting gear should be checked to determine if it will hold under load. The oil of gear reduction units should be checked for proper amount, temperature, and purity. Periodic inspections should be made of the pressure lubrication fittings normally installed on slow moving parts. On installations which use hydraulic transmission, the pumps and lines are maintained in the same way as those of any other hydraulic system.

Cranes

Cranes are designed to meet the following conditions:

1. Hoist, lower top, and rotate rated load at the specified speed, and against a specified list of the ship.
2. Handle 150 percent rated load at no specified speed.
3. Withstand a static, suspended load of 200 percent rated load without damage or distortion to any part of the crane or structure.

The types of cranes installed on ships vary in accordance with the equipment handled. Cranes are classified as <u>general type</u> and <u>type of drive</u> as follows:

1. General Type
   a. Rotating king post.
   b. Stationary king post.
   c. Fixed topping lift.
   d. Variable topping lift.
   e. Jib.
2. Type of Drive
   a. Electrohydraulic.
   b. Straight electric.
   c. Gasoline engine.
   d. Diesel engine.
   e. Hand operated.

Components of Cranes

The crane equipment generally includes the boom, king post, king post bearings, sheaves, hook and rope, machinery platforms, rotating gear, drums, hoisting, topping and rotating drives, and controls. The important components are described in the paragraphs which follow.

BOOMS.—A boom, used as a mechanical shipboard appliance, is a structural member utilized for lifting, transferring, or supporting heavy weights. A boom is used in conjunction with other structure or structural members which support it, and various ropes and pulleys, called blocks, which control it.

KING POSTS.—A king post of either the rotating or stationary type is provided, as necessary, to meet the lift requirements of the ship.

KING POST BEARINGS.—On stationary king posts, bearings are provided for taking both vertical load and horizontal strain at the collar, located at the top of the king post. On rotating king posts, bearings are provided for both vertical and horizontal loads at the base, and for horizontal reactions at a higher deck level.

SHEAVES AND ROPES.—The hoisting and topping ropes are led from the drums over sheaves to the head of the boom. The sheaves and ropes are designed in accordance with recommendations by the Naval Ship Systems Command, which gives the criteria for selection of sheave diameter, size, and flexibility of the rope. Sufficient fair-lead sheaves are fitted to prevent fouling of the rope. A shock absorber is installed in the line, hoisting block or sheave at the head of the boom, to take care of shock stresses.

MACHINERY PLATFORMS.—Machinery platforms are provided for carrying the power equipment and operator's station. These platforms are mounted on the king post above the deck.

ROTATING GEAR AND PINIONS.—Rotation of the crane is accomplished by means of vertical shafts with pinions engaging a large rotating gear.

DRUMS.—The drums of the hoisting and topping winches are generally grooved for the proper size wire rope. The drums in the latest designs are arranged to stow the rope in one layer in order to facilitate spooling and to prevent crushing of the rope. The hoisting system is arranged for use with single or mulitple part lines as required. The topping system is arranged for use with a multiple purchase as required.

Operation and Maintenance of Cranes

The hoisting whips and topping lifts of cranes are usually driven by hydraulic variable-speed gears, through gearing of various types. This provides the wide range of speed and delicate control required for load handling. The cranes are usually rotated by an electric motor connected to worm and spur gearing, or by an electric motor and hydraulic variable-speed gear connected to appropriate reduction gearing.

Some of the electrohydraulic cranes are also provided with automatic slack line takeup equipment, consisting of an electric torque motor geared to the drum. When these cranes are used for lifting boats, aircraft or other loads from the water, the torque motor assists the hydraulic motor drive to reel in the cable in case the load is lifted faster by the water than it is being hoisted by the crane.

Electrohydraulic equipment for the crane consists of one or more electric motors, running at constant speed. Each motor drives one or more A-end variable displacement hydraulic pumps whose strokes are controlled through operating handwheels. START, STOP, and EMERGENCY RUN pushbuttons are located at the operator's station for the control of the electric motors. Interlocks are provided to prevent starting the electric motors when the hydraulic pumps are on stroke. B-end hydraulic motors are connected to the A-end pumps by piping, and drive the drums of the hoisting and topping units or the rotating machinery.

Reduction gears are provided between the electric motor and the A-end pump and between the B-end hydraulic motor and the rotating pinion. Each hoisting, topping, and rotating drive is provided with an electric brake on the hydraulic motor output shaft. The electric brake is so interlocked with the hydraulic pump control that the brake will set when the hydraulic control is on neutral or when electric power is lost. A centering device is provided for accurately finding and retaining the neutral position of the hydraulic pump.

Relief valves are installed for the protection of the hydraulic system. These relief valves are normally set at 150 percent of the normal working pressure.

A rapid slack-takeup device consisting of an electric torque motor, which is connected to the hoist drum through reduction gearing, is usually provided on cranes. This device works in conjunction with the pressure stroke control on the hydraulic pump, and provides for fast acceleration of the hook in the hoisting direction under light hook conditions. Thus, slack is prevented from forming in the cable when hoisting is started.

Some cranes are provided with a light-hook paying-out device. This device is mounted on the end of the boom to pay out the hoisting cables when the weight of the hook and cable beyond the boom head sheave is insufficient

to overhaul the cable as fast as it is unreeled from the hoisting drum.

When the mechanical hoist control is in neutral, the torque motor is not energized and the cable is gripped lightly by the action of a spring. Moving the hoist control to LOWER energizes the torque motor, and the sheaves clamp and pay out the cable as it is unreeled from the hoist drum. When the hoist control is moved to HOIST, the torque motor is reversed and operates to unclamp the sheaves. A limit switch opens and automatically deenergizes the paying-out device. Figure 16-8 shows the light-hook pay-out device with the torque motor paying out the cable.

Maintenance of cranes should be accomplished in accordance with the planned maintenance system requirements or the manufacturers' instructions. In general, the maintenance of electrohydraulic cranes requires that the oil in the replenishing tanks be kept at the prescribed levels, and that the system be kept clean and free of air. The limit stop and other mechanical safety devices must be checked regularly for proper operation. When cranes are not in use, they should be secured in their

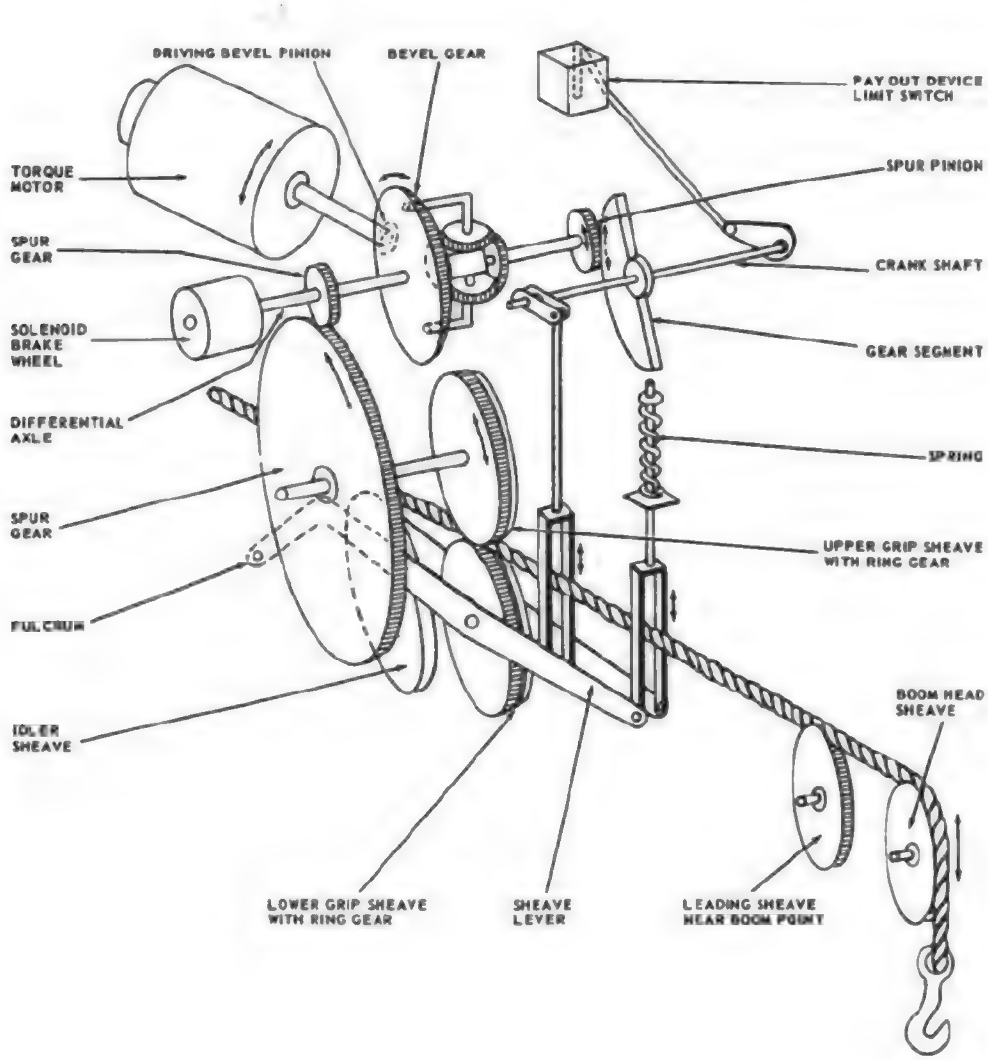


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Figure 16-8.—Light hook pay-out device.

stowed positions and all electric power to the crane controllers disconnected at the power distribution panel.

ELEVATORS

Some of the hydraulic equipment which you may be required to maintain will be found in electrohydraulic elevator installations. Elevators of this type are in use on modern carriers. The elevators described in this chapter are of the type now in service on some of the more recent ships of the CVA class. These ships are equipped with four deck-edge airplane elevators which have a maximum lifting capacity of 79,000 pounds to 105,000 pounds. The cable lift platform of each elevator projects over the side of the ship and is operated by an electrohydraulic power plant.

Power Plant

The electrohydraulic power plant consists of the following:

1. A horizontal plunger type hydraulic engine.
2. Multiple variable delivery parallel piston type pumps.
3. Two high pressure tanks.
4. One low pressure tank.
5. Sump tank system.
6. Two constant delivery vane type pumps (sump pumps).
7. Oil storage tank.
8. Piping system and valves.
9. Nitrogen supply.

The hydraulic engine is operated by pressure developed in a closed hydraulic system. Oil is supplied to the system in sufficient quantity to cover the baffle plates in the high pressure tanks and allow for piston displacement. Nitrogen makes up the rest of the volume. Nitrogen is used because air and oil in contact under high pressure form an explosive mixture. Air should not be used except in an emergency; nitrogen, when used, should be maintained at 97 percent purity.

Principles of Operation

The hydraulic engine is fitted with a balanced piston type valve with control orifices and a differential control unit. This control assembly is actuated by an electric motor and can be operated by hand. To raise the elevator, the valve is moved off center, allowing high pressure oil to enter the cylinder. High pressure oil entering the cylinder, moves the ram, which, through a system of cables and sheaves, moves the platform upward. The speed of the elevator is controlled by the amount of pressure in the high pressure tank and the control valve.

When the elevator starts upward, the pressure in the high pressure tank drops. This pressure drop automatically starts the main pumps which transfer oil from the low pressure tank to the high pressure system until the pressure is restored. An electrical stopping device automatically limits the stroke of the ram and stops the platform at the proper position at the flight deck level.

To lower the elevator, the control valve is moved in the opposite direction, which permits the oil in the cylinder to flow into the exhaust tank. As the platform descends, oil is discharged to the low pressure tank and the original oil levels and pressures, except for leakages, are reestablished. The speed of lowering is controlled by the control valve and the cushioning effect of the pressure in the exhaust tank. Leakage is drained to the sump tanks and is automatically transferred to the pressure system by the sump pumps. An electrically operated stopping device automatically slows down the ram and stops the platform at its lower level (hangar deck).

Safety Features

Some of the major safety features incorporated into modern deck edge elevators include the following:

1. If the electrical power fails while the platform is at the hangar deck, there will be enough pressure in the system to move the platform to the flight deck one time without the pumps running.
2. Some platforms are fitted with serrated safety shoes. Should all hoisting cable break on one side, the shoes will wedge the platform between the guide rails and stop the platform with a minimum of damage.
3. Some main pumps are fitted with (1) pressure actuated switches which stop the pump motors when the discharge pressure reaches 1140 psi, and (2) a relief valve set to lift at 1270 psi.
4. The sump pump system has a capacity sufficient to return the unloaded platform from the hangar deck to the flight deck.

5. The oil filter system may be used continuously while the engine is running, thus part of the oil may be cleaned with each operation of the elevator.

MAINTENANCE OF HYDRAULIC SYSTEMS

As an MM, you must know how to renew packing on hydraulic engines and how to change seals and gaskets on hydraulic equipment. Details concerning any specific unit can be found in the Planned Maintenance System Manual or the appropriate manufacturer's technical manual. The information which follows will also be helpful. While the following section applies specifically to hydraulic elevators, the information is also applicable in general to most shipboard hydraulic systems.

REPLACING HYDRAULIC ENGINE CYLINDER PACKING

As the plunger moves in and out of the cylinder, the cylinder packing confines the pressure in the cylinder and prevents leakage of oil. The packing is made up of several split rings. To prevent leakage, the cylinder gland nuts must be tightened periodically. If the gland nuts have been tightened and the packing continues to leak excessively, the packing is worn or damaged and must be renewed.

To renew the packing, proceed as follows:

1. Lock the platform at the flight deck.
2. Set the stroke of the main pumps at zero and close all pressure tank, exhaust tank, and strainer valves.
3. Drain the oil from the cylinder, through the engine drain line. When oil stops draining, close the drain line.
4. Remove the gland nuts and the gland.
5. Remove the oil packing rings.
6. Insert new packing rings in the packing gland. Stagger the splits in the rings at 90° intervals. It may be necessary to support the ram in order to insert new packing on the underside of the ram.
7. Replace the gland and nuts. Care must be taken to pull the nuts up evenly and only to the point where they are snug.
8. Open all valves to the exhaust and pressure tank and open the engine air cocks.
9. Check to be certain that the main pump handwheels are set at zero stroke. Start the main pump motors and set the pumps on automatic control.
10. Open the control valve slightly, by rotating the hand control valve counterclockwise, until the oil flows from the engine air cocks.
11. Close the control valves.
12. Tighten the packing gland nuts one turn at a time until oil leakage, through the packing gland, is a few drops per second. (Nuts should be tightened so that the gland is drawn up evenly.) Some oil leakage is necessary for proper lubrication of the packing.
13. Loosen each nut one-half turn and lock with jam nut.

CAUTION: If the packing is too tight the plunger will not operate at proper speed and may also damage the packing.

14. Bleed all the air from the cylinder and pressure line.
15. Check the oil levels and pressures before placing the elevator in service. An oil seal is provided for wiping the plunger of foreign material on the in-stroke. It is split and can be removed after sliding off the plate.

REPLACING MAIN SHAFT OIL SEALS

When the main shaft oil seals become worn or damaged and cause excessive oil leakage, replace the seals as follows:

1. Disconnect the universal joint from the main shaft by removing the bolt.
2. Shove the main shaft toward the motors.
3. Remove the fork and the plate (part A of fig. 16-9).
4. Remove the old seal and replace it with a new seal (part B of fig. 16-9).
5. Reassemble the seals with the plate, fork, and universal joint (part C of fig. 16-9).

REPLACING MOTOR SHAFT OIL SEALS

To determine the condition of the motor pinion assembly and associated oil seals, make periodic inspections for excessibe leakage. If

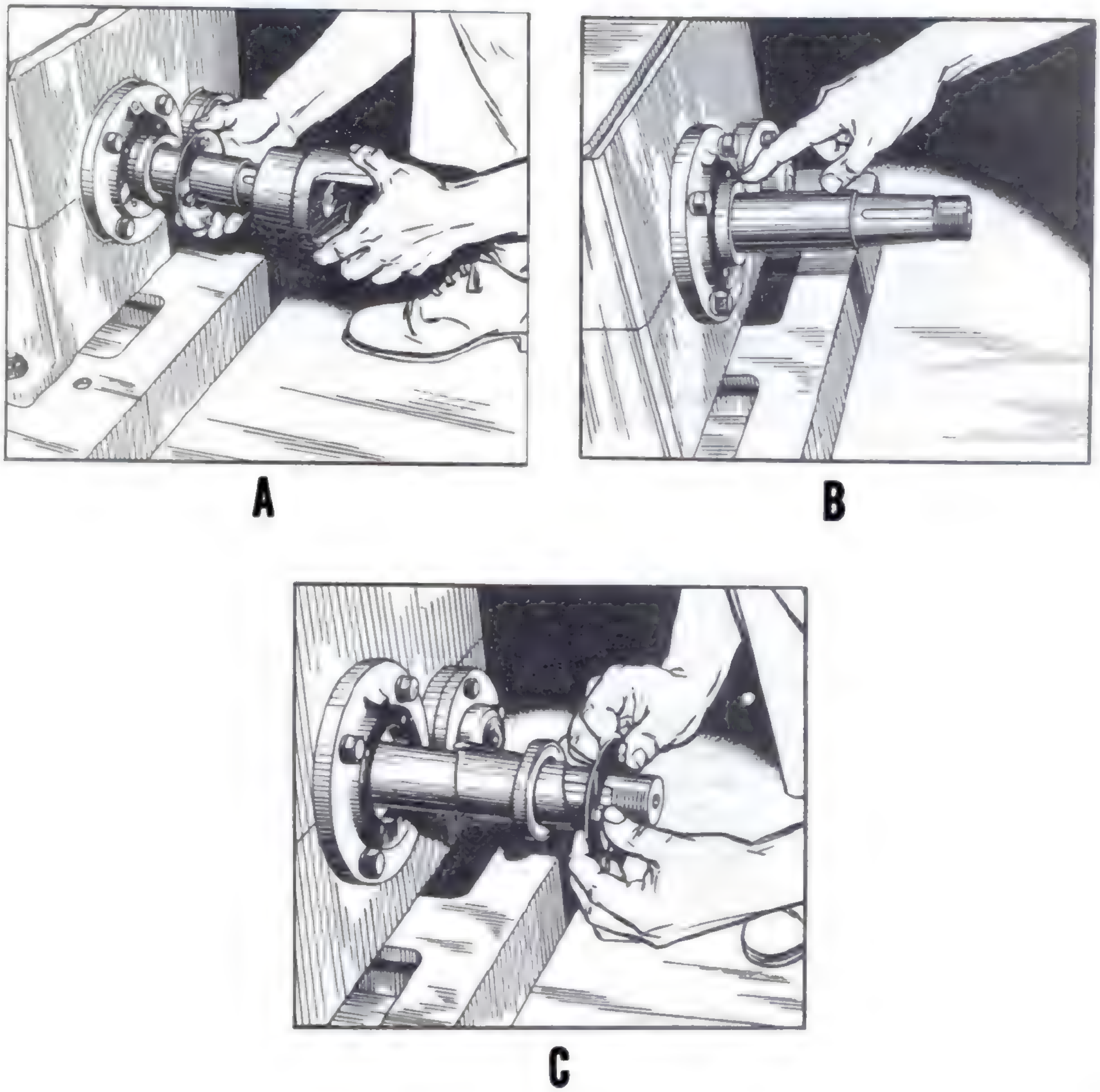

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Figure 16-9.—Replacing main shaft oil seals. A. Removing fork and plate. B. Removing oil seal. C. Reassembling oil seal and plate.

it becomes necessary to replace the motor shaft oil seals, proceed as follows:

1. While supporting the motors, remove the bolts fastening the motor blocking to the mounting bracket.

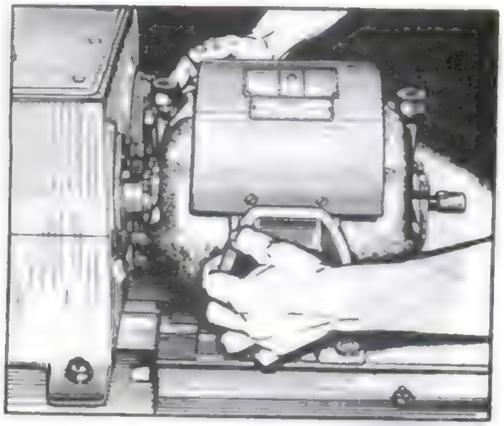
2. Pull the motors horizontally away from the gear box until the pinion on the motor shaft is clear of the gear box (part A of fig. 16-10).

3. Remove the oil seals and replace them with new seals (part B of fig. 16-10).

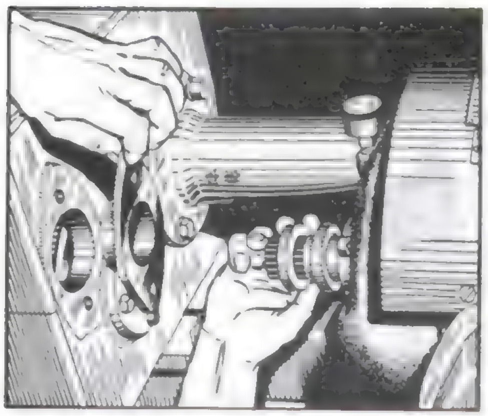
4. Return the motor pinion into the gear box, and bolt the motor blocking, or frames, into place (part C of fig. 16-10).

CLEANING MAIN AND SUMP PUMP OIL STRAINERS

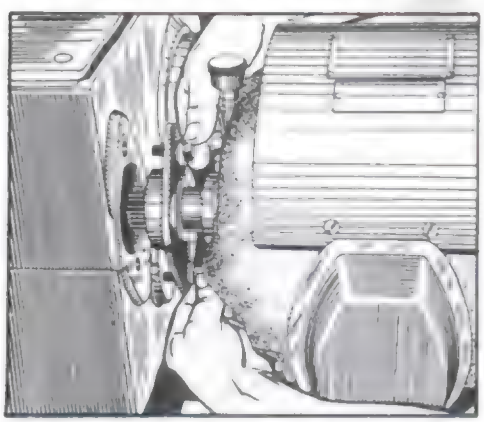
The main pump oil strainers should be cleaned shortly after the hydraulic system has



A



B



C

47.148

Figure 16-10.—Replacing motor shaft oil seals. A. Pulling motors. B. Replacing oil seals. C. Returning motor pinion into gear box.

been filled with oil, or after repair work has been completed. (It is possible that foreign matter, such as dirt, metal chips, and filings may have entered the system.) To clean a main pump oil strainer, proceed as follows:

1. Close the strainer intake (inlet) valve and the main pump suction valve.
2. Open the air cock, at the top of the strainer, and the drain valve, at the bottom of the strainer. This will drain the oil from the strainer into the sump tank.
3. Close the drain valve.
4. Loosen the bolts and remove the cover from the strainer (part A of fig. 6-11).
5. Lift the basket out of the strainer (part B of fig. 16-11).
6. Blow out all dirt and foreign matter from the strainer basket. Then clean the strainer basket thoroughly (part C of fig. 16-11).
7. Insert the basket into the strainer, place the cover on the strainer (using a new gasket), replace and tighten the bolts.
8. Open the strainer intake valve and refill the strainer with oil from the system while bleeding off the air.
9. Close the air cock and open the main pump section valves.

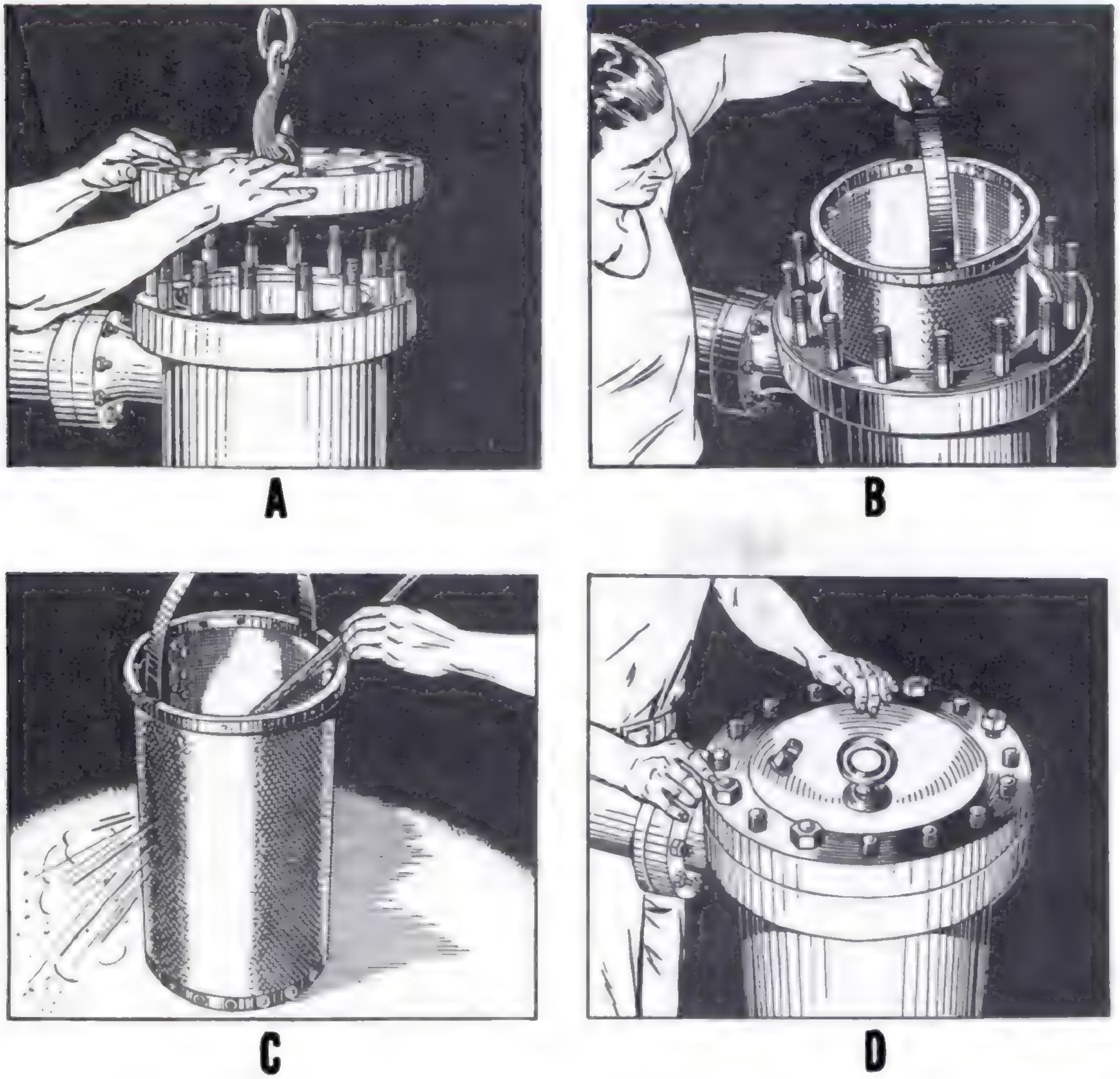
The sump pump oil strainers should be cleaned at the same time as the main pump oil strainers. They are cleaned by the following procedure:

1. Close the storage tank stop valve, the exhaust tank stop check valve, the engine stop check valve, and the sump pump stop check valve.
2. Open the air cock and the drain valve. Then continue the procedure as outlined under main pump strainers, and remember to open the check valves before refilling the strainer with oil.

CARE OF MAIN HYDRAULIC PUMPS

Maintenance of the main pump consists mainly of draining and refilling with oil, when the oil in the hydraulic system has become dirty or mixed with water. In addition, the compensator control filter should be cleaned at least once each week.

To drain the pump, open the drain valve at the bottom of the unit. When the pump is



47.149
Figure 16-11.—Cleaning main and pump oil strainers. A. Removing strainer cover. B. Lifting strainer basket. C. Cleaning strainer basket. D. Replacing strainer cover.

drained, clean out dirt and sludge, and flush the pump with acid-free cleaning fluid. Wash out all cleaning fluid and blow the pump dry with an air hose before refilling with fluid.

Use fire resistant, or safety, fluid MIL-H-19457 in the hydraulic system. All oil must be strained through a fine mesh wire screen as it is poured into the system. The use of cloth strainers is not recommended, since the continued use of such material tends to cause an accumulation of lint in the system. This may result in the sticking of the pistons. A convenient accessory for filling may be made by soldering a piece of fine mesh wire screen to an ordinary funnel. In some cases the usefulness of the funnel is increased by the addition of a pipe thread at the lower end. By connecting this funnel to a length of pipe, the funnel may be used for filling purposes in places that are not otherwise accessible.

See that all containers used for filling the system, or for storing oil, are clean. They must not have been used previously for acids, lyes, or other chemicals. When the pump is drained after having been in service, all dirt and sludge must be cleaned out, and the pump flushed with acid-free cleaning fluid. Before refilling with oil, all cleaning fluid must be removed from the pump, and the pump blown out with air until dry. Unless this is done, either the chemical or the physical properties of the oil may be impaired by small quantities of cleaning fluids.

In elevator hydraulic systems, water seeping into the pump will usually settle in low points. If the drain plugs are removed, the water will come out.

Hydraulic equipment which has been standing idle at extremely low temperatures should be started with care. (Before operating the equipment the entrapped air should be bled from the cylinders, control valves, strainer, and piping.) While the oil is pumpable at low temperatures, it does not lubricate properly. A short time is required to force the oil between closely fitted parts so as to provide lubrication. Two or three minutes' operation at low pressures will provide ample time for penetration. During this time the oil will warm up and the viscosity will be greatly reduced.

Grit and abrasive particles in the oil will cause wear which destroys the seal between the pistons and the cylinder. This results in the leakage losses which reduce the efficiency beyond allowable limits. If the wear becomes excessive, the worn part should be replaced.

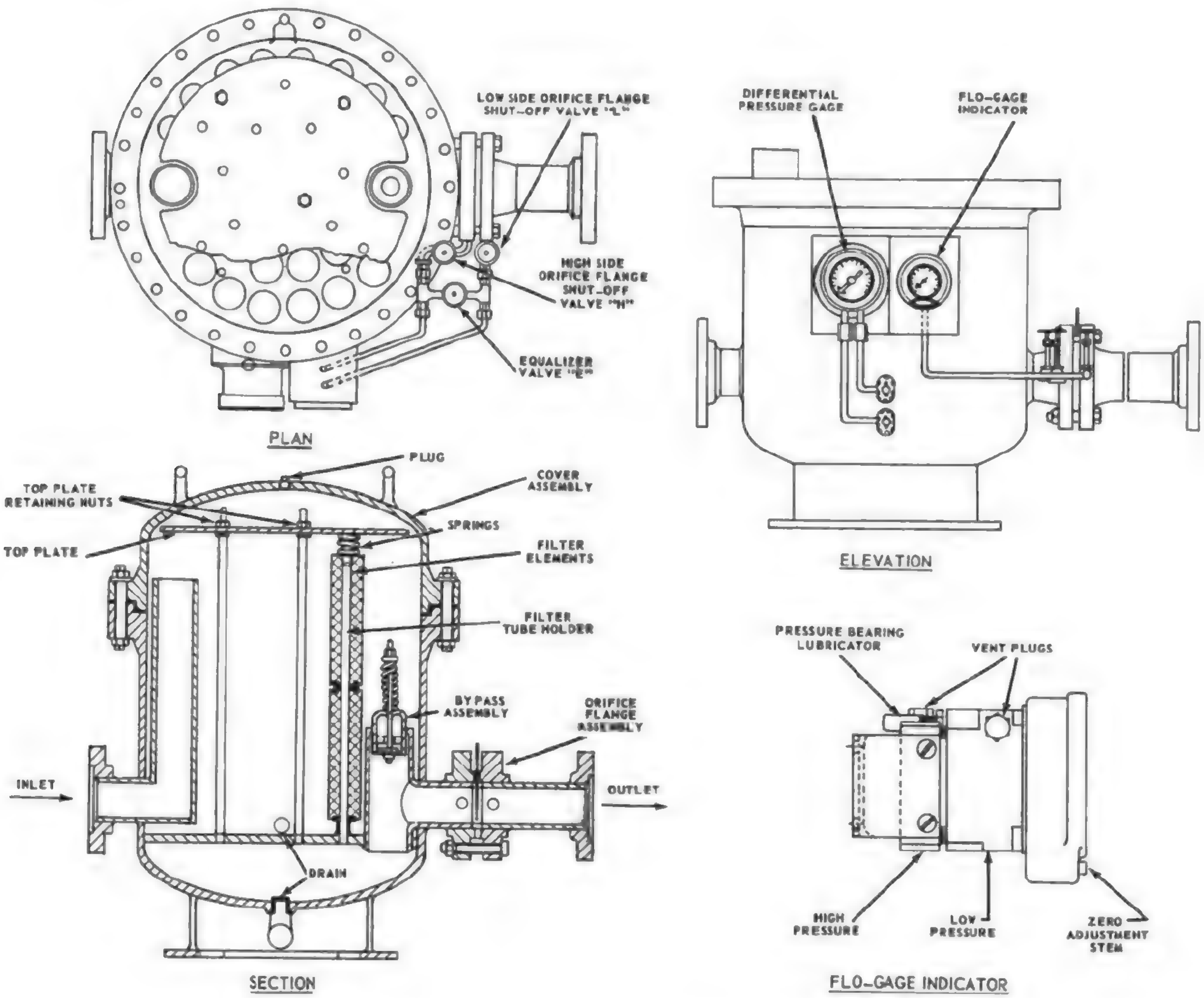
CLEANING AND REPLACING FILTER ELEMENTS

Each elevator has a micronic oil filter (fig. 16-12) installed in its power system. The filter is generally designed to handle approximately 140 gpm of hydraulic oil, at a working pressure of 350 psi. The quantity of oil passing through the unit is controlled by an orifice installed between the flanges located on the discharge side of the filter. The quantity of oil will be indicated on the Flo-Gage and the pressure gage. An internal bypass valve is installed and set to open at 20 psi above the working pressure. Stop valves are installed on the inlet and outlet sides of the filter to facilitate cleaning and/or replacement of the filter elements. The piping to the filter is arranged to take oil from the exhaust tank and discharge to the suction sides of the main pumps.

To clean all the oil in the enclosed pressure system, operate the elevator on a cycle once "up" and "down"; this takes approximately 3-1/2 minutes. Use at least one of the main pumps to circulate the oil. Shorten the strokes of the pumps to reduce delivery so that the pumps are not automatically shut down between runs of the elevator. Close the inlet and the outlet valves of the main strainers; this will cause all the oil being pumped to pass through the filter. Watch the Flo-Gage and adjust the strokes of the pumps so that the flow does not exceed 140 gpm. Operate the elevator as frequently as necessary to keep the pumps operating, i.e., run the elevator up and down before the oil level and pressure are completely restored in the high pressure tank which would shut off the pumps. Maintain this operation for about 30 minutes—in which time, all the oil should have passed through the filter. Observe the differential pressure gage and if the indication is above 5 psi, stop filtering and clean the filter. After the complete cleaning of the oil, the filter can be used in parallel with the main strainer. This condition will allow about 10 percent of the oil to flow through for continuous filtering during the normal operation of the elevator.

To clean the filter, proceed as follows:

1. Place the Flo-Gage in the inoperative position.
2. Close the inlet and the outlet gate valves.
3. Slowly open the globe valve in the drain line from the bottom of the filter.
4. Open the gate valve in the drain line from the side of the filter body.
5. Close the globe valve in the drain line from the bottom of the filter.
6. Attach the air hose (25 psi) to the 1/4-inch size needle valve and allow air to blow back through the filter elements, through the open gate valve to the blow-down tank.
7. Close the drain and air valve, and allow the oil to settle in the flow-down tank after which a check for the cleavage point can be made by using the try cocks on the tank. Impurities in the oil can be disposed of through the 1/2-inch valve installed below the blow-down tank.
8. When refilling with oil, or fluid, open the plug on top of the filter to bleed the air.
9. Open the outlet valve, and the inlet valve. Close the plug when all the air is out.
10. Place the Flo-Gage in operation.



47.150
Figure 16-12.—Micronic oil filter.

If the filter cannot satisfactorily be cleaned, replace the filter as follows:

1. Proceed as for cleaning the filter elements; steps 1 through 4.
2. Remove the filter cover assembly, the top plate retaining nuts, the top plate, and the filter elements.
3. Before replacing the elements, wipe out any sediment on the bottom of the chamber.
4. Replace the filter elements on the filter tube holder and springs.
5. Before replacing the top plate, see that the element holders and springs are all evenly in place. Replace the top plate, the top plate retaining nuts, and the cover assembly.
6. Place the filter in operation by proceeding as in steps 8, 9, and 10 of the cleaning procedure.

CLEANLINESS OF HYDRAULIC SYSTEMS

Dirt or foreign matter in hydraulic systems can disable pumps, cause valves to stick, ruin

packing, and damage control systems. Hydraulic systems should never be opened except for good cause and then only by qualified personnel. When it is necessary to open a hydraulic system, extreme care should be taken to keep out dirt; all parts should be carefully cleaned before being reinstalled. Oil filters should be cleaned or changed in accordance with the 3-M Planned Maintenance System requirements. Any oil added to the system should be filtered. Only clean oil of an approved type should be added to a hydraulic system. Use only approved packing and gasket materials and never allow water to enter a hydraulic system.

Complete maintenance of all types of hydraulic systems cannot be given in this training manual. Maintenance instructions for a particular unit may be found in the Planned Maintenance System Manual or in the technical manual furnished by the manufacturer.

MAINTENANCE OF GALLEY AND LAUNDRY EQUIPMENT

Most of the equipment used in the preparation of food and in the sanitizing of cooking utensils utilizes electrical power. The electrical components of such equipment are usually maintained by the Electrician's Mate. The mechanical components of the smaller machines used in the galley require very little maintenance and that required will generally be performed by operating personnel. The Machinist's Mate will most likely be called upon to maintain larger items of galley equipment, many of which utilize steam as a source of heat. Such equipment includes steam-heated cooking equipment and dishwashing machines.

Each piece of laundry equipment (washing machines, extractors, driers, ironers, and laundry presses) should be inspected and maintained in accordance with the 3-M Planned Maintenance System or applicable procedures outlined in the manufacturer's technical manual for the specific equipment. Adjustments, repairs, and replacements should be made as soon as possible after the need for maintenance is revealed by an inspection.

Before proceeding with the maintenance and repair of galley and laundry equipment, you should be familiar with the type of equipment you'll have to maintain.

DISHWASHING MACHINES

The Navy uses dishwashers of the single-tank and the double-tank types. Both types are available in manual and automatic models. One model of an automatic single-tank dishwashing machine is shown in figure 16-13.

Single Tank Machines

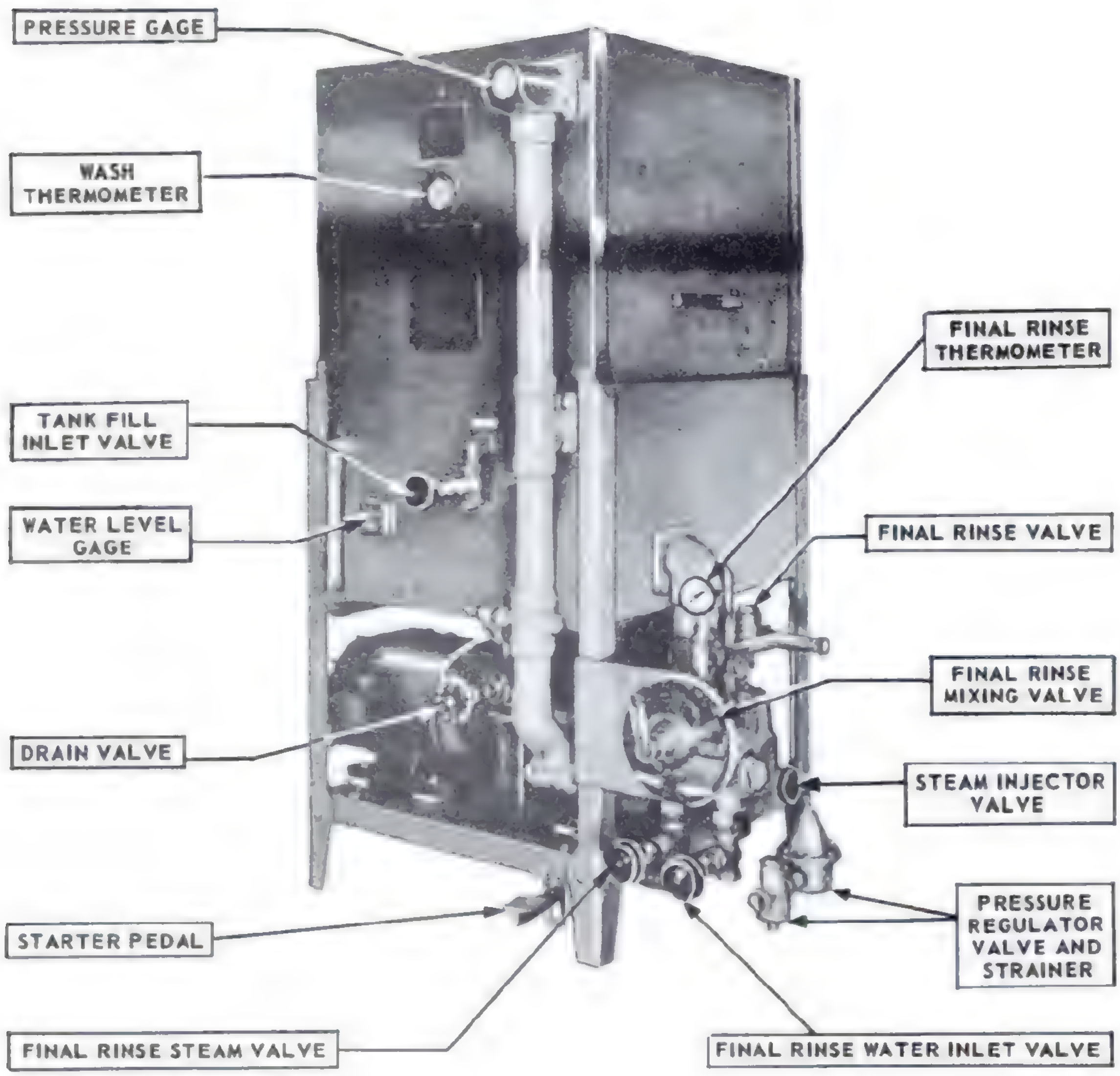
In single tank machines the temperature of the wash water in the tank should be between 140°F and 160°F. Rinsing is accomplished by means of hot water which is sprayed on the dishes from an outside source. The rinse water is controlled by an adjustable automatic STEAM-MIXING VALVE which maintains the temperature of the rinse water between 180° and 195°F. Washing and rinse sprays are controlled separately by automatic valves in the automatic machine, and by handles in the manually operated machine.

Double Tank Machines

Double tank machines of several sizes are in use. Machines of the double tank type are generally used when the utensils for more than 150 persons are to be washed. These machines are provided with separate wash and rinse tanks and a final rinse of hot water is sprayed on the dishes from an outside source. The final rinse is controlled by a self-closing valve which is opened by the baskets as they pass through the machine. The final rinse is fitted with an adjustable automatic steam-mixing valve which maintains the temperature of the rinse between 180° and 195°F. Double-tank machines are equipped with a thermostatically operated switch in the rinse tank which prevents operation of the machine when the temperature of the rinse water is lower than 180°F. Dish baskets pass through the machine automatically by means of conveyor chains.

Maintenance of Dishwashing Machines

If high health standards are to be maintained on board ship, it is essential that dishwashing machines be maintained in satisfactory operating condition. The following inspection should be made



47.160
Figure 16-13.—Automatic single-tank dishwashing machine (model 50SA-7).

in accordance with the Planned Maintenance System requirements.

1. Check the tension on the conveyor chains of machines so equipped; make adjustments if necessary. If both chains are equipped with lugs, see that these lugs are directly opposite each other.

2. Check to see that guide sprockets are located on their shaft so that the conveyor chain rides properly on the track assembly.

3. On single-tank machines, inspect the operation of the doors; be sure that all counterweights are properly attached and that they hold the doors open when the doors are raised.

4. After the machine has been placed in operation in accordance with prescribed operating instructions, check the operation of all thermometers, pressure gages, and thermostats, and of the automatic mixing valve or booster heater.

The thermostat on the rinse tank of a double-tank machine should be adjusted so that the

machine cannot be started unless the temperature in the rinse tank is 180°F or higher.

The automatic mixing valve should be adjusted to maintain the temperature of the water at or above 190°F when the rinse valve is open.

5. Inspect the pump packing and adjust it as necessary to stop leakage around the pump shaft.

6. Check the force of the recirculating wash spray.

Hold a tray inside the machine to deflect the spray from the upper spray assembly further into the machine; the lower spray, when not meeting the upper spray, should rise approximately to the top of the machine. If this is not occurring, there is insufficient spray velocity to produce satisfactory results. The cause of the trouble should be determined and corrected. The trouble may be caused by:

a. Pump-suction line blocked.
b. Spray-tube cap missing.
c. Spray-tube missing.
d. Jet orifices excessively worn.
e. Pump running backward.
f. Pump impeller corroded.

7. Ascertain whether the conveyor on a conveyor-type machine is functioning in the proper manner.

8. Determine whether the final-rinse valve on a double-tank machine is functioning in a satisfactory manner; and whether, when the valve is opened, a uniform spray is coming from each of the orifices.

9. Clean the orifices of the spray valve if necessary.

10. Lubricate motor and pump bearings.

11. Check and lubricate, as necessary, the gear reducer unit.

12. Lubricate the conveyor-shaft bearings, drive mechanism, and sprocket chains.

13. Replace any missing lubrication fittings.

14. Inspect all steam and water valves.

15. Adjust gland nuts as necessary to prevent leakage.

16. Fill the tanks to the normal operating level, but do not open any steam valve; observe the water for a period of 5 minutes to determine whether there is an appreciable reduction in the water level. When there is an excessive reduction in the water level, check the drain valves for leakage.

17. Fill the tanks to the overflow opening and determine whether the overflow drain is functioning to prevent the water level from rising above the overflow opening.

18. Clean the drains and the overflow if necessary. The pumps should be disassembled and inspected at least once a year. Inspect the pump rotors to determine whether they are excessively eroded or corroded.

Descaling of Dishwashing Machines

Excessive scale deposit on the inside of piping and pumps clogs them and interferes with the efficient performance of dishwashing machines by reducing the volume of water that comes in contact with the utensils in the washing and sanitizing process. In addition, deposits within the machine provide an ideal place for dangerous bacteria to collect. Dishwashing machines should be descaled as often as necessary to prevent scale from interfering with the operation of the machine. The following method of descaling dishwashing machines may be used:

1. Fill the tanks half way to the overflow level with hot clean water.

2. To prepare the cleaning solution, add to the water in each tank 7 fluid ounces of orthophosphoric acid 85 percent and 1/2 fluid ounce of wetting agent for each gallon of water the tank will hold when it is filled to the overflow level. (When the capacity of a tank is not known, the inside dimensions (inches) of each tank may be used in the following formula to calculate the capacity in gallons; length times width times depth (to the water line) divided by 231 equals capacity in gallons.)

3. Complete the filling of the tanks to the overflow level.

4. With scrap trays, spray arms, and curtains in place, operate the machine for 30 minutes at the highest temperature possible.

5. Remove the cleaning solution completely by draining the tanks; rinse the tanks thoroughly by refilling them with fresh hot water and then operating the machine for five minutes. The rinsing procedure should be repeated several times.

Lubrication of Dishwashing Machines

The points of lubrication and the schedule to be followed will vary depending on the type and

design of each machine. The following schedule for one type of automatic double-tank dishwashing machine is typical:

1. Turn the grease cups on the pump-shaft bearings one or two turns each week. (If oil cups are installed, keep the cups near the overflow level.)
2. Check the level of oil in the speedreducer case every three months. Oil should be added when the oil level is below the oil-level plug.
3. Turn the grease cups on the drive-end of the conveyor once a week and refill them when they are empty; if cups are not provided, oil the bearings with a few drops of recommended oil each day.
4. Turn the grease cup on the rinse lever once a week; refill the cup when it is empty.
5. Apply a few drops of oil to the revolving wash arm whenever the motor is oiled.
6. Oil should be placed in the cups on the motor once each week unless the bearings are of the ball type; some ball bearings need greasing once a year, others need no periodic lubrication. Check to be sure of the type of bearing in use.

CAUTION: A dishwashing machine must not be lubricated or repaired when the machine is in operation.

Repair of Dishwashing Machines

To the extent that they are applicable, these general instructions should be followed when dishwashing machines need adjustment or repair:

1. Repair strainer pans as soon as they are damaged or become defective; if pans are warped, straighten them so thay lie flat in the machine.
2. Adjust the speed of the conveyor in automatic machines so that the washing and rinsing intervals are as recommended by the manufacturer.
3. Repair torn or worn curtains; replace them when they are beyond repair.
4. When the pump does not deliver enough water to the spray nozzles, remove the inspection plate and clean the pump housing. Impellers which are worn or damaged beyond repair should be replaced. Be sure the replacements have the correct dimensions and design.
5. When the packing around the pump shaft leaks, tighten the packing nut lightly; excessive tightening causes the packing to bind the shaft, which in turn overloads the motor and causes scoring of the shaft and the packing to wear excessively.
6. Replace worn gland packing. Do not put more packing than necessary in a packing gland; excess packing will bind the shaft when the packing nut is tightened.
7. Replace damaged thermometers.
8. Make necessary adjustments and replacements on conveyors to ensure satisfactory operation.

On some machines, the speed reducer for the conveyor is driven by a V-belt from the pump shaft. This belt will often stretch after the machine has been in operation for some time. To tighten the belt, first loosen the set screw on the outside portion of the belt pulley; then turn the outside half of the pulley so that the pitch diameter is changed sufficiently to tighten the belt. After the proper tension has been obtained, tighten the pulley set-screw.

9. Keep inspection doors on wash and rinse compartments watertight at all times. Leaks may result from a bent door; in such cases, straighten the door to make a tight fit. If the door still fits improperly, check the grooves in which the door slides and remove any accumulation of rust or other obstructions.
10. Check chains and pulleys of counterbalanced doors for defects. Oil moving parts and joints regularly to ensure smooth operation.
11. Repair dish racks as soon as defects are noted.
12. Adjust or repair steam coils, traps, and thermostats.

STEAM-HEATED COOKING EQUIPMENT

Some of the galley equipment which you will inspect and maintain utilizes steam as a source of heat. Some of this equipment, such as steam cookers, steam-jacketed kettles, and proofing cabinets, has few, if any, moving parts which require maintenance. In equipment of this type, your primary concern will be the maintenance of the valves and the piping which supply steam to the unit.

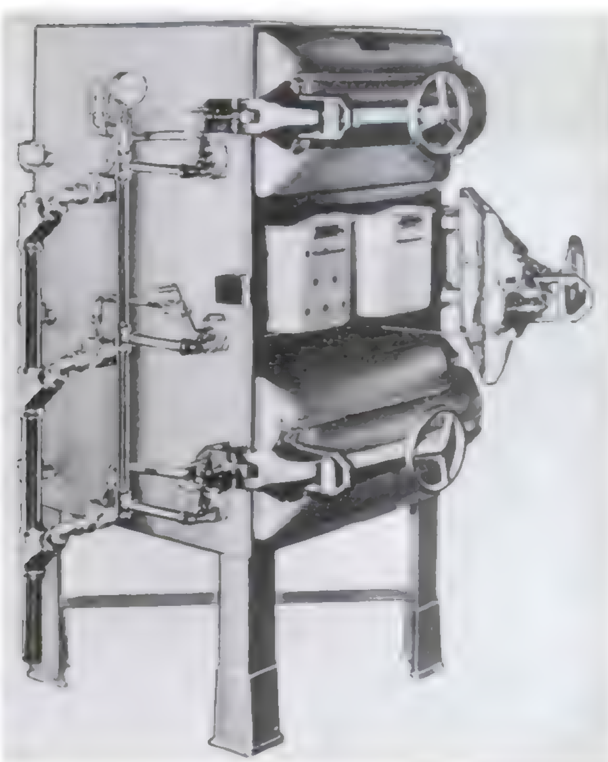
Steam Cookers (Steamers)

Some large galleys are equipped with a steamer that is used for cooking vegetables.

Steam cookers are made of cast iron or steel, and have three or more compartments equipped with heavy doors operated by handwheels. Live steam that heats the steamer is controlled by a PRESSURE-REDUCING VALVE. Steam which does not condense escapes through the BLOW-OFF VALVE, and, in case of excess pressure, through the SAFETY VALVE. (See figure 16-14.)

The doors of a steam cooker are of the full-floating type; that is, they are suspended on supporting arms which are hinged to the side of the cooker. The doors are closed by wheel-operated ball-bearing pressure screws on the door arms; the door arms apply equalized pressure at the center of the doors. When the doors are closed, a seal is maintained by endless gaskets of special rubber composition.

Each compartment is supplied with steam through a quick-closing safety THROTTLE VALVE which is so arranged that the compartment doors cannot be opened until steam is shut off. Each compartment is provided with a separate outlet and valve arrangement to prevent the intermingling of odors from various compartments.



47.161
Figure 16-14.—Steam cooker.

An evaporating compartment is located under the steam compartments. The evaporating compartment is equipped with a STEAM COIL and STEAM-CONTROL VALVE, HAND WATER-FEED CONTROL VALVE, DRAIN VALVE, SAFETY VALVE and WATER-LEVEL GAGE. An access door is provided to facilitate cleaning of the evaporating compartment.

Steam cookers require a minimum of maintenance. The following repairs, replacements, and adjustments should be made on steam cookers whenever necessary.

1. GASKET REPLACEMENT. Remove the door and place it on a work bench. Remove the old gasket and clean the channel thoroughly; take care not to chip or damage the channel.

Apply the recommended gasket cement, and insert the new gasket. Force the gasket into the channel at the corners and then work it toward the center of each end and side.

Rehang the door and close it lightly. Before closing the door tightly, place paper over the door opening to keep excess gasket cement from adhering to the mating surfaces of the door and cookers.

Leave the door closed until the cement sets. Clean off surplus cement.

2. DOOR-FIT ADJUSTMENT. Some full-floating doors are adjustable, others are not. When adjustment is possible, the doors and gaskets may be adjusted by turning the hexagon-head bolts which extend through the door, near each corner. When a replacement gasket is installed, adjust the bolts so the closed door touches the body of the steamer evenly and does not bind at any corner. If the door is not adjusted properly, the gasket will be cut by the corners of the door.

3. LOCKING DEVICE ADJUSTMENT. If a plunger-type valve is used in conjunction with the locking device, adjust the plunger so that the valve is fully open when the door is closed and allows the full amount of steam to enter the compartment. Adjust the valve so it stops the steam supply completely when the steam door is opened.

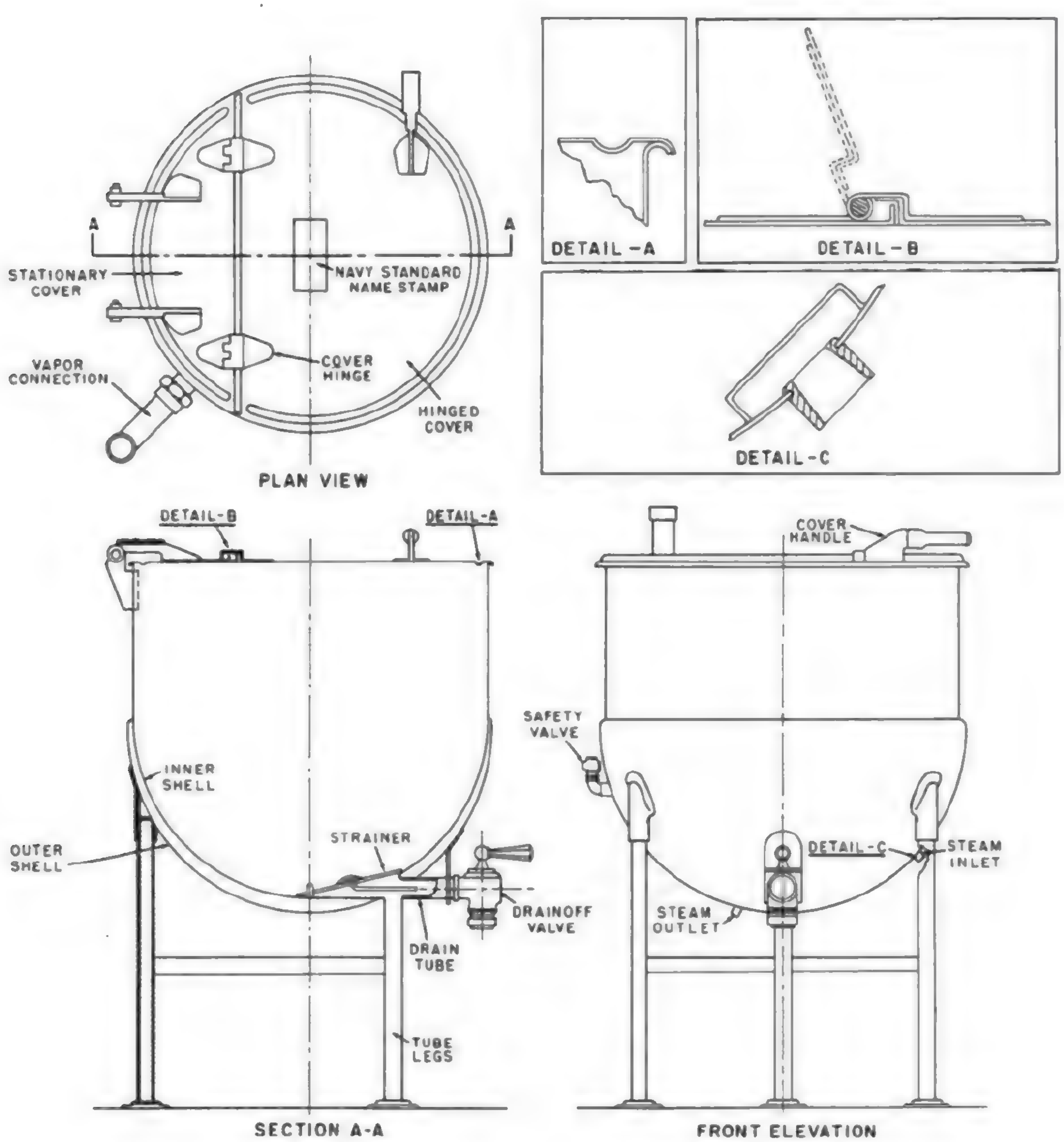
4. STEAM VALVE REPAIR. When repacking a steam valve, install packing which fits, enters easily, and draws up evenly. When winding coil packing around the valve stem, force the packing to the outer edge of the stuffing box instead of wrapping it tightly around the valve stem;

after adding the maximum number of packing rings, draw up packing gland evenly and make the nut handtight.

5. PIN AND BUSHING REPLACEMENT. The hinge pins and bushings of compartment doors should be replaced when they are excessively worn.

Steam Jacketed Kettles

Kettles were originally made of copper; they are now made of aluminum or corrosion-resistant steel. Kettles used by the Navy range in size from 10 to 80 gallons and are of the stationary type. (See fig. 16-15.)



47.162
Figure 16-15.—Steam-jacketed kettle.

The kettle illustrated is typical of most steam-jacketed kettles used by the Navy. The lower two thirds of the kettle is surrounded by a JACKET, which is set off from the main body of the kettle to provide space for steam to circulate and thus heat the contents of the kettle. Stationary kettles are generally mounted on three legs, have a HINGED COVER and a tube at the bottom of the body of the kettle with a DRAW-OFF FAUCET. A SAFETY VALVE is provided to release pressure from the jacket when the pressure exceeds the design limit. Most kettles are designed to operate on a maximum steam pressure of 50 pounds per square inch.

WASHING MACHINES

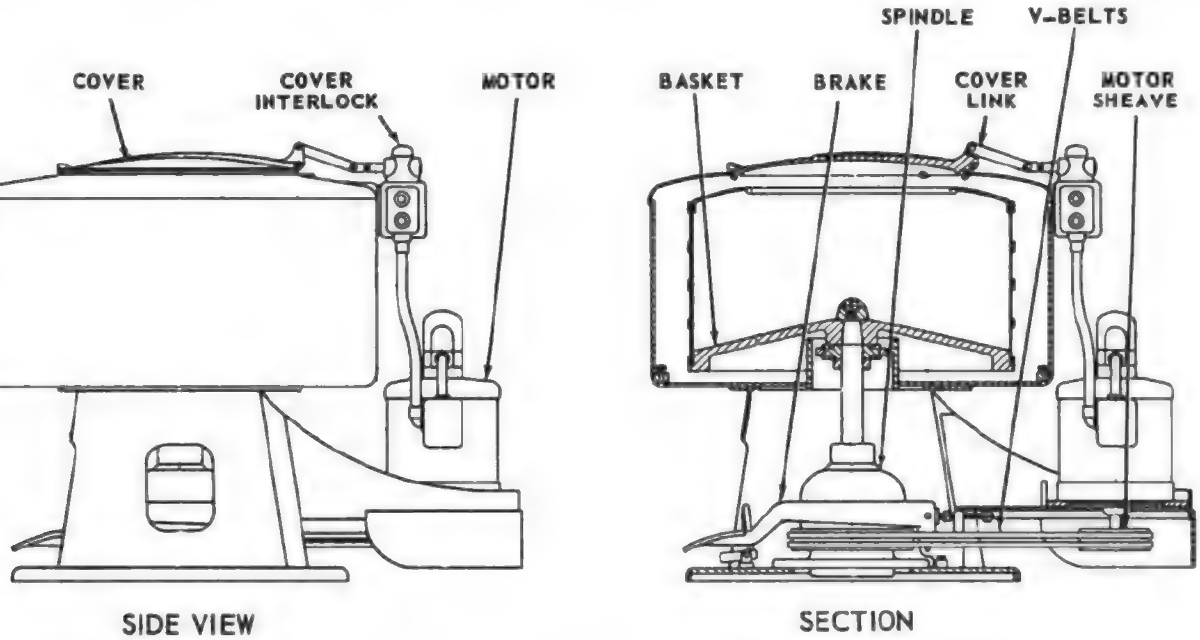
The following inspections and adjustments of washing machines should be made in accordance with planned maintenance systems requirements:

1. Check all gear-casing gaskets and stuffing boxes; they must be tight to keep water from entering the gear casing.
2. Check the mechanical condition and functioning of thermometers, water-level indicator, and timer, if fitted.
3. Check the tightness of steam valves and water-filling valves.
4. Check the tightness of the dump valve by filling the machine with water to the 6-inch level and determining whether, with all filling valves closed, water level drops more than one inch in ten minutes. An excessive rate of drop in water level indicates the need for valve repair or replacement.
5. Inspect the trunnion packing; adjust or replace as necessary.
6. Check the cylinder-door latches to determine whether they are functioning properly; latches should hold the door securely in both the open and closed positions. Latches should be kept as tight as possible at all times; looseness hastens wear of the cylinder door, door latches, and latch parts. Cylinder-door latches are of a tapered, self-adjusting type, and automatically compensate for wear within reasonable limits. When wear exceeds the range of automatic take-up, the latch-keeper must be readjusted.
7. Check the magnetic brake to determine whether it holds the cylinder securely in the proper position for unloading, and whether it releases properly when power is applied to the controller.
8. Determine whether the machine is running smoothly and whether it is reversing the direction of rotation in a regular periodic manner without excessive vibration or shock during reversals. Make any necessary adjustments in the tension of sprocket chains and belts. (The Electrician's Mate will determine whether the adjustment of the timing-motor controller is correct.)
9. Check the operation of the shell-door interlock switch.
10. Check for any loose nuts, tap bolts, or screws; all such fastening devices should be fitted with lock washers or other suitable locking devices.
11. Inform the Electrician's Mate when faulty operation of the machine is believed to be caused by defective electrical equipment.
12. Remove all gear guards, belt guards, and sprocket-chain guards.
13. Inspect all gears, sprocket chains, and belts for wear. Adjust the tension of sprocket chains and V-belts to ensure best performance. On a large machine driven by a sprocket chain on each end, the chains must be carefully synchronized and have the same degree of tension.
14. Check the trunnion bearings on each end of the shaft and all intermediate bearings for excessive wear; lubricate the bearings as necessary.
15. Clean all parts of the machine.
16. Replace the guards and make sure that all nuts, tap bolts, and screws are fitted with lock washers or other locking devices.

LAUNDRY EXTRACTORS

The following inspections and adjustments of laundry extractors (fig. 16-16) should be made in accordance with Planned Maintenance System requirements:

1. Check the mechanical condition and the functioning of the cover safety interlock.
2. Check the adjustment on the pressure pads which support the spindle and basket.
3. Check the bumper ring to determine whether it is in satisfactory condition and functioning properly.
4. Check belt tension; adjust the belts as necessary.
5. Check the functioning of the brake; the brake should bring the extractor to rest within three-fourths of a minute after power has been interrupted and the brake applied.



22.14(47)
Figure 16-16.—Laundry extractor.

6. Check the drain-like connection and be sure that it is open. When the connection is clogged, water will overflow around the spindle shaft and damage the drive mechanism.
7. Removal of the belt guard examination of the belts; replace the belts if necessary.
8. Inspection of the basket and bands for possible defects. Particular attention should be given the strengthening bands; if defective, the bands may fall because of the high stresses imposed when the machine is operating at high speed.

The supporting flanges for the bearing housing of an extractor are mounted between rubber pads. The pads permit some oscillation of the extractor basket when the machine is in operation. The amount of oscillation is controlled by the pressure on the pads. A pressure nut is provided for making the necessary ADJUSTMENTS TO THE PADS. The pressure nut incorporates a locking set-screw which should be loosened before any adjustments are made. The set screw should be tightened when the adjustment is completed. A special spanner wrench is provided for turning the pressure nut. The pressure should be adjusted so that a 20-pound pull at the top of the basket will cause a movement of not more than one-eighth inch. In order to prevent excessive oscillation when the ship rolls the pressure must be maintained considerably higher than on extractors installed ashore.

Particular attention must be given to the INSPECTION OF BASKET BANDS. Rust may accumulate between the bands on the basket in such a way as to give the appearance of a double band in good condition; actually the metal may be greatly reduced in effective area and strength by corrosion. Special care is necessary to detect the true condition of the bands. Prod, scale, or take such other steps as are practicable to determine the condition of the strengthening bands. Should doubt arise as to the condition of the basket and the strengthening bands, steps should be taken to obtain a new basket. On recent extractors the baskets and reenforcing bands are made of corrosion-resistant metal.

COMBINATION WASHER-EXTRACTOR MACHINES

Periodic inspections of combination washer-extractor machines should be made to ensure that:

1. Hold-down bolts are tight.
2. V-belts are adjusted properly.
3. Nuts, bolts, and screws are tight.

4. Seals and gaskets are tight.
5. Surfaces are clean and free of dirt.
6. Moving parts are properly lubricated.

A properly adjusted V-belt can be depressed 1/4 inch, midway between the pulleys. A V-belt that is tightened excessively will wear rapidly. A V-belt that is adjusted too loosely will slip. V-belts may be tightened by loosening the lower nuts on the motor-plate adjusting screws and tightening the upper nuts, then adjusting nuts equally.

The supply door must seal to prevent leaking. Occasionally the supply door locking assembly must be adjusted to compensate for gasket wear. To adjust, regulate the adjustment nuts on the lock lever loop to increase tension on the supply door lid hook.

The clutch must be kept in proper adjustment. A slipping clutch will overheat and wear out quickly.

The brake wears to some extent even under the best operating conditions. As the brake bands wear, adjustment should be made to keep the braking time constant (35 seconds). To adjust the brake, proceed as follows:

1. Remove belt guard.
2. Turn notched wheel on brake cylinder until brake drum is handtight.
3. Back off notched wheel 5 notches (adjust each shoe in the same manner).
4. Replace belt guard.
5. Make certain that the machine is bolted tightly to the fountain, steel to steel, no gaskets to minimize vibration.

TUMBLER DRIERS

The following checks and adjustments of tumbler driers should be made in accordance with planned maintenance system requirements:

1. Check the mechanical condition, and the functioning of the thermometer, if installed. (The thermometer is generally installed in the air-discharge duct leading from the tumbler cylinder.)
2. Check the tightness of all valves and the functioning of steam traps to ensure that when the valves are open, the coils are uniformly heated.
3. Inspect steam heater-coils; clean the coils when necessary, using an air hose or vacuum cleaner.

The heater coils of tumbler driers are generally arranged in two banks with separate steam connections to each bank. In most cases valves are provided on both the inlet and the drain side of each bank.

4. Remove the covers from all clean-out openings and clean all lint and dust from the machine and from the air-discharge ducts.
5. On end-loading tumblers, check the cylinder-door latches and determine whether the door is held firmly when it is in the closed position. On side-loading tumblers, check the cylinder-door latches and determine whether the latches hold the door securely in both the open and closed positions.
6. On side-loading tumblers, check the magnetic brake to determine whether it securely holds the cylinder in the proper position for unloading, and whether the brake releases properly when power is applied to the controller.
7. On side-loading tumblers, determine whether the machine is running smoothly and is reversing its direction of rotation in a regular periodic manner without excessive vibration or shock during reversals. Make any necessary adjustments in the tension of sprocket chains and belts.
8. On all side-loading tumblers check to determine whether all dampers are set so that there is no recirculation of air within the drier.
9. On side-loading tumblers, check the operation of the shell-door interlock.
10. Remove the guards and inspect all gears, sprocket chains, and belts for wear. Adjust the tension of sprocket chains and V-belts to ensure best performance. Replace parts which are worn excessively.
11. Check the trunnion bearings and all intermediate shaft bearings to determine whether there has been excessive wear; replace bearings when they are worn excessibely. Lubricate all bearings as required.
12. Clean all parts of the machine.
13. Replace the guards; be sure that all nuts, tap bolts, and screws are fitted with the necessary lock washers or other locking devices.

FLAT-WORK IRONERS

The following checks and adjustments are generally included in the planned maintenance system requirements for flat-work ironers:

1. Check the tightness of all valves and the functioning of steam traps; be sure that when the valves are open, the cylinder is uniformly heated.

2. Check the packing of the cylinder steam-joints and adjust as necessary to prevent steam leakage.

The packing is held in place by a spring. If a joint shows more than a reasonable amount of leakage, check the packing for excessive wear. If the packing is not worn excessively, the packing spring may be broken.

3. Check the operation of the safety guard and the interlock switch.

All gear guards, belt guards, and sprocket-chain guards should be removed periodically from flat-work ironers. In addition, periodic inspections, checks, and adjustments outlined in the applicable technical manual, should be included as follows:

1. Inspect all gears, sprocket chains, and belts for wear. Adjust tension of sprocket chains and V-belts to ensure best performance.
2. Check the trunnion and roller bearings and all intermediate bearings to determine whether there has been any excess wear; lubricate the bearings as required.
3. Clean all parts of the machine.
4. Replace all guards; make sure that all nuts, tap bolts, and screws are fitted with the necessary locking devices.
5. The steam cylinder of a flat-work ironer should be given a HYDROSTATIC TEST at the pressure recommended by the manufacturer.

LAUNDRY PRESSES

Manual presses are used extensively in shipboard installations; many ships, however, are equipped with air-operated presses. In general, inspection of laundry presses will include the following checks and adjustments.

1. Check the mechanical condition of the machine to determine whether the head, when released, returns smoothly and without shock to the fully-open position; adjust counterbalance springs, shock-absorber cylinder, and air vent as necessary.
2. Fill the shock-absorber cylinder (if so equipped).
3. Inspect all valves to determine whether they are functioning without leakage.
4. Inspect the steam traps. If they are not functioning properly the head and buck will not be heated uniformly and there will be an excessive loss of steam.
5. On air-operated presses, make sure that neither of the air-control valves has been by-passed and that they are so adjusted as to require the use of both hands to close the press and apply pressure.
6. Check to determine whether excessive pressure is required on the foot pedal to lock the head in the pressing position. If excessive pressure is required, check for an excessive amount of padding; if the padding is satisfactory, check the linkage of the head pressure-mechanism.
7. Removal and cleaning of all air filters.
8. Examination of the cups on the closing cylinders and pressure cylinders; replace the cups if they are badly worn.

All press-heads and bucks should be given an ANNUAL HYDROSTATIC TEST at the pressure recommended by the manufacturer.

LUBRICATION OF LAUNDRY EQUIPMENT

Lubrication is an important part of the inspection of each piece of laundry equipment. The lubrication charts furnished with each piece of equipment should be checked for the location of lubrication fittings for the lubricants to be used. The location of the fittings as they appear on the chart for one type of flat-work ironer are shown in figure 16-17.

In general, all bearings and sliding surfaces of each piece of laundry equipment must be checked at least once a week and lubricated as recommended by the manufacturer of the machine. Oil and grease cups should be filled to the recommended level and grease should be added through all pressure grease fittings. All lubrication fittings should be checked; any fittings that are missing, damaged, or broken should be replaced. The sprocket chains of tumbler driers and washing machines are generally lubricated through drip type oil cups; these cups should be kept full.

SAFETY DEVICES ON LAUNDRY EQUIPMENT

Each piece of laundry equipment is provided with one or more safety devices. Since they are designed to protect the operator of the machine, safety devices must be maintained in proper working condition at all times. The inspection of safety devices is included as a

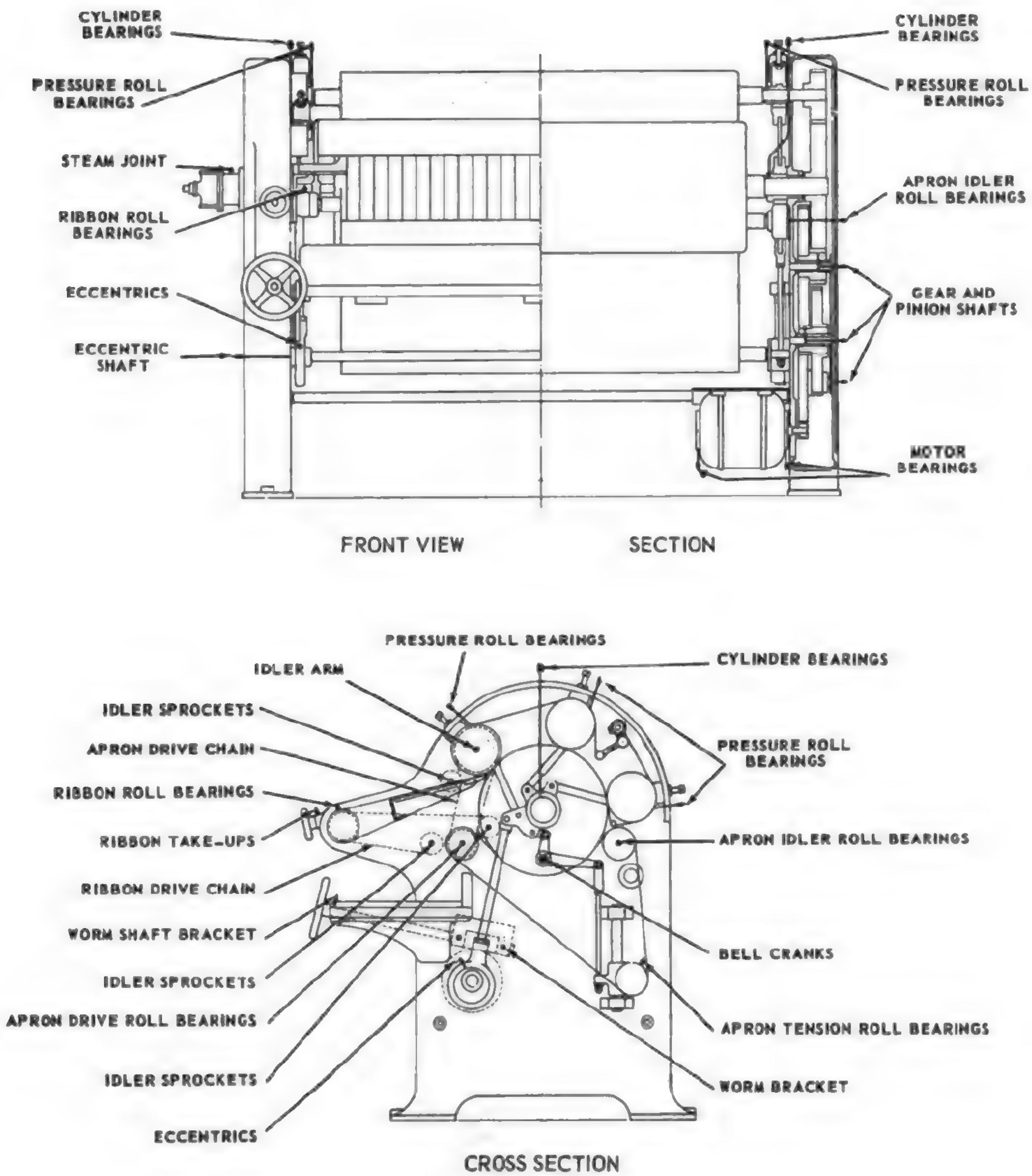


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Figure 16-17.— Points of lubrication for a flat-work ironer.

part of the periodic inspections of laundry equipment. If a safety device is removed from a machine for any reason, the device must be replaced and be in satisfactory operating condition before the machine is again put in operation. Some of the safety devices which you may be required to adjust and maintain are described in the following paragraphs.

Safety Interlocks

The covers of laundry extractors are fitted with safety interlocks. The interlock is designed to keep the cover of an extractor from being opened while the basket is rotating, and to keep the machine from being started when the cover is open. On some recent extractors, there is an interlock between the brake and the safety switch; this interlock keeps the brake from being applied while the motor is energized, and keeps the machine from being started when the brake is set. In all cases, the STOP button should be operated to deenergize the motor before the foot brake is applied; and the foot brake must be released before the START button is used.

The cover safety-lock mechanism on laundry extractors includes a connecting rod which connects the portion of the interlock mechanism mounted on the top of the curb with the portion of the mechanism that is mounted underneath the curb. Generally, the components of interlock mechanisms will function reliably. The connecting rod between the portions of the interlock mechanisms may become bent, however, if considerable force is applied in opening the door of the extractor.

The connecting rod of an interlock mechanism should be checked regularly and frequently. If the rod is found to be bent or if there is an indication that the rod may become deformed when considerable force is applied in opening the cover of the extractor, a larger cold-rolled steel rod should be substituted for the original rod. For example, if a five-sixteenth-inch rod is in use, a one-half inch rod will serve satisfactorily as a substitute. The ends of the substitute rod should be turned down and threaded to fit the presently installed clevises. If a larger rod is indicated but is not available, the existing rod should be straightened and a piece of close-fitting steel tubing or iron pipe whould be slipped over the rod to increase its stiffness.

The hinge pins and clevis pins of many safety-interlock mechanisms are held in place by cotter pins which can be removed readily. In order to make it more difficult for unauthorized personnel to disconnect the safety-interlock mechanism, upset or rivet as many of the pins as practicable.

Washing machines and tumbler driers of the side-loading type also are equipped with safety interlocks. On these machines the interlocks prevent starting the machine while the door in the outer shell is open; and, when the cylinder is in motion, they either stop the machine automatically when the door in the outer shell is opened or prevent the door being opened.

Safety Guards

Flat-work ironers are always equipped with a safety guard or bar which extends along the front of the machine. The arranegment is such that the operator's hands will push the guard before they can enter the rolls of the machine. When the guard is pushed, a safety switch which stops the motor is activated. Some return-apron flat-work ironers have an added safety device which either applies a brake or declutches the motor when the safety guard is pushed. Safety guards should be inspected regularly and frequently; you must be sure that they are properly in place and performing their function. Safety guards which do not stop the motor when the guard is pushed must be adjusted or replaced before the machine is again operated.

All exposed gears, chains, and belts on laundry equipment are fitted with guards or shields. These guards must be in place and in satisfactory condition when equipment is put in operation.

Pushbutton Valves

The two operating valves of air-operated laundry presses are of the pushbutton type. The arrangement of the valves is such that both hands of the operator must be used to operate the press; the hands of the operator, therefore, cannot be caught in the press when it closes. The pushbutton valves must not be bypassed or left permanently open.

INDUSTRIAL GASES

Historically, the first gas to be put to large-scale commercial use was coal gas, obtained by distilling coal in retorts. In this process, coal is heated in containers which shield it from air,

and thereby prevent combustion, thus driving off gas from the coal, leaving coke. The city gas industry developed so rapidly in the last century, especially in England, that to most people the word "gas" became synonymous with the cooking, heating, and lighting gas mixture supplied by the gas companies. Coal gas is known as "producer gas"; oil is known as "natural gas"; their chief components are METHANE and other HYDROCARBONS. Hydrocarbons, as the word itself signifies, are components formed of carbon and hydrogen. Similar gases are developed in the process of "cracking" oil to produce gasoline, and those gases are known as "cracker gases."

Air consists mostly of oxygen and nitrogen, plus small percentages of the inert gases, argon, neon, krypton, and xenon. Methods of separating the constitutents of the atmosphere have been developed and many important industrial uses for these components have been found.

Only a few Machinist's Mates are engaged with the actual generation or compression of industrial gases, and then only after special training. All men of this rating, however, are required to handle one or all of the several compressed gases used aboard ship. It is important, therefore, that you have a general understanding of the characteristics as well as the uses of these gases.

GENERAL NATURE OF GASES

Before discussing the physical properties and characteristics of specific gases, let us briefly summarize the general nature of gases.

ALL GASES ARE COMPRESSIBLE; that is, they can be forced into spaces of lesser volume than they occupy under normal conditions. You are probably familiar with the two GAS LAWS (discussed in Fireman, NAVPERS 10520-D) which express the relationship of the gas pressure with its volume and temperature; BOYLE'S LAW and CHARLES' LAW.

The TEMPERATURE FACTOR is important in handling gases, for when the temperature of a gas in a container is increased, the pressure increases on all parts of the container. Consider an automobile tire, for example. The air in the revolving tire gains heat from the warm pavement, and from friction. This added heat energy increases the molecular activity of the air within the tire. The tire appears to have accumulated more air, as indicated by the increased pressure against the tire walls (the tire actually expands due to the increased pressure). Let the tire cool, however, and the pressure returns to normal.

Gas cylinders are not elastic and do not expand from the pressure of the gas within them. Cylinders are, therefore, filled with compressed gases only to the maximum safe pressure at normal atmospheric temperatures. Storage of the cylinders in hot spaces will increase the pressure of the confined gases to a dangerously high point, where the cylinders will explode. The boiling points for the various liquefied gases are important. Various gases have to be separated from each other. Their different boiling points make this possible. As an illustration of this principle, take a mixture of water and alcohol in an automobile radiator: Alcohol boils at 172°F, but water boils at 212°F; the alcohol therefore begins to evaporate and separate from the water before the water nears the boiling point. As the water is never allowed to reach 212°F, the alcohol content grows less and less as the temperature rises above 172°F. The same process is employed in separating and purifying gases.

GAS CHARACTERISTICS

In addition to knowing the general nature of gases, you should know some of the distinguishing features of the gases utilized by the Navy, and the special precautions to be exercised in handling industrial gases. From a standpoint of volume used by the Navy, the gases oxygen, carbon dioxide, acetylene, and nitrogen together with various refrigerants, lead all others by far. Figure 16-18 shows the characteristics of gases. However, the discussion which follows deals with the characteristics of acetylene, carbon dioxide, oxygen, and nitrogen, and the safety precautions to be followed when handling each of the industrial gases.

Acetylene

Acetylene is a chemically produced gas which is not found in the natural state. In 1892, a method for the commercial production of the chemical CALCIUM CARBIDE was discovered. It is from calcium carbide and water that acetylene is produced. In 1895, it was discovered that acetylene, combined with oxygen and burned, has the ability to produce high temperatures.

NAME	SYMBOL	ODOR	FLAMMABILITY PERCENT BY VOLUME IN AIR		AUTO-IGNITION TEMPERATURE	DENSITY RELATIVE TO AIR AIR = 1	VAPOR PRESSURE AT 68° F. P.S.I.	WEIGHT IN POUNDS OF 1 CUBIC FOOT AT STANDARD ATMOSPHERIC PRESSURE AND 68° F.	PHYSICAL STATE WHEN SHIPPED	REMARKS
			LOWER	UPPER						
Acetylene	C_2H_2	Garlic	2.5	80	635	0.90	663.57	0.06754	Dissolved	Shipped dissolved in acetone 250 psi at 70°F.
Air	------	None	----	--	-----	1.00	(a)	.07528	Gas	Critical point below 68°F.
Ammonia	NH_2	Pungent	16	25	1,436	.59	124.34	.04420	Liquid	
Argon	A	None	----	--	-----	1.38	(a)	.10389	Gas	Inert gas
Carbon dioxide	CO_2	do.	----	--	-----	1.52	830.47	.1142	Liquid	do.
Chlorine	Cl_2	Pungent	----	--	-----	2.44	96.58	.1839	do.	Reacts with hydrogen
Refrigerant 12	CCl_2F_2	None	----	--	-----	4.17	67.54	.3136	do.	Inert
Refrigerant 22	$CHClF_2$	do.	----	--	-----	2.99	122.00	.2243	do.	do.
Ethyl chloride	C_2H_5Cl	Sweet	3.6	14.8	-----	2.22	19.55	.1664	do.	
Ethylene oxide	C_2H40	do.	3	80	804	1.52	------	.1142	do.	
Helium	He	None	----	--	-----	.14	(a)	.01039	Gas	Critical point below 68°F.
Hydrogen	H_2	do.	4.1	74.2	1,076	.07	(a)	.00523	do.	do.
Inert gas	------	None	----	--	-----	1.05 (approx).	(a)	.079	--------	Inert
Methyl chloride	CH3Cl	Ether	8.2	19.7	------	1.74	69.82	.1309	Liquid	
Nitrogen	N_2	None	----	--	------	.97	(a)	.07274	Gas	do.
Nitrous oxide	N_2O	Ether	----	--	------	1.52	739.41	.1143	Liquid	
Oxygen	O_2	None	----	--	------	1.10	(a)	.08305	Gas	do.
Propane	C_3H8 b/	Rotten cabbage c/	2.37	9.5	871	1.55	129.36	.1143	Liquid	
Sulfur dioxide	SO_2	Pungent	----	--	------	2.21	47.78	.1663	do.	
Butane	$C4H_{10}$ b/	Rotten cabbage c/	1.6	8.5	806	2.04	30.6	.1507	do.	

a/ Gas can not be liquefied at 68° F. Cylinder pressure is determined by amount of gas in the cylinder.

b/ Fuels of which the major constituent has the indicated chemical symbol.

c/ Propane and butane generally are odorless in the natural state, and are artificially odorized as an aid for detecting leaks.

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Figure 16-18.—Characteristics of gases.

By the turn of the century, acetylene was being used for lighting, both commercially and domestically. Even today acetylene is used in lighthouses and buoys because of its exceptional brilliance while burning.

Acetylene (C_2H_2) is a colorless gas. When pure it has a sweet odor, but when impure, usually with HYDROGEN SULPHIDE as an impurity, it has a disagreeable odor. Hydrogen sulphide is the gas that produces the well known "rotten eggs" smell. Acetylene is shipped dissolved in ACETONE in cylinders that contain a MONOLITHIC (the cylinder is filled throughout with the same mixture of asbestos, charcoal, cement, and diatomaceous earth. Diatomaceous means composed of the skeletons of various forms of sea life) filler. Acetone is a liquid ORGANIC compound which is used as a solvent for many other organic compounds. Roughly, an organic compound is any one that contains carbon (C); note that acetylene (C_2H_2) is an organic compound formed by combining two atoms of carbon with two atoms of hydrogen.

Acetylene is stable and safe to handle as charged in Navy standard acetylene cylinders. But in the free gaseous state, or if compressed in cylinders not designed for acetylene, the gas is very unstable and likely to decompose violently. In large volumes, at pressures exceeding 15 psi, acetylene is dangerously explosive. This means that acetylene can "explode of its own accord" (spontaneous ignition) when improperly stored or handled. It does not always need air, or oxygen, or a spark to help it explode. Any shock or heat may be enough to set acetylene off if it is stored at pressures higher than 15 psi.

When mixed with air or oxygen, the chances of violent explosion are doubled. The explosive limits of acetylene in air range from 3 to 82 percent acetylene with maximum effect at approximately 7.8 percent. Acetylene in copper piping systems, or in piping systems with silver-brazed joints, may form acetylides by combining with copper or silver. Acetylides so formed are violently explosive and are capable of being detonated by shock or heat.

Acetylene mixed in controlled proportions with oxygen in the acetylene torch produces an intensely hot flame. Its uses in welding and cutting are well known.

The SAFETY PRECAUTIONS for acetylene should be emphasized again and again. You will be held strictly accountable for knowing and observing these rules yourself, and you should make every effort to see that others handling acetylene know and observe them.

The safety rules for acetylene are as follows:

1. Acetylene should never be discharged into hose lines and manifolds at a pressure greater than 15 psi. A suitable pressure-reducing regulator should be employed on all occasions.
2. Acetylene cylinders should be used or stored only in an upright position, valve end up, to avoid the possibility of withdrawing acetone when the cylinders are being discharged. Do not open the cylinder valve more than 1 1/2 turns of the spindle.
3. Do not recharge acetylene cylinders or transfer acetylene from one cylinder to another without specific approval from the Naval Ship Systems Command. It is possible to charge or refill acetylene cylinders safely only with special equipment. Acetylene cylinders contain a porous material with minute cellular spaces, so that no pockets of appreciable size remain where free acetylene in the gaseous state may collect. In addition, acetone partially fills the cellular spaces and acts as a solvent for the acetylene. While in the dissolved state, acetylene is stable. It should be clear by now that NO OTHER TYPE cylinder should be used to store acetylene gas.
4. Keep sparks and flames away from acetylene cylinders, and under no circumstances allow a flame to come in contact with the safety devices. Never allow the cylinders to contact electric welding apparatus or electrical circuits.
5. Where it is necessary to test for leaks, use soapy water.
6. Do not interchange acetylene regulators, hose, or other appliances with similar equipment intended for other gases.
7. Do not use acetylene manifolds which are not approved by the Naval Ship Systems Command.
8. Use no wrench other than the one designed for opening the cylinder, and keep the wrench on the cylinder while it is in use.
9. Should a cylinder catch fire, use a wet blanket to extinguish the fire; if this fails, spray a stream of water on the cylinder.

Carbon Dioxide

Carbon dioxide (CO_2) is a colorless, odorless gas and 1.52 times as heavy as air. It can be condensed into a colorless liquid and stored in this state, under pressure, in cylinders. When the cylinder valve is opened, gaseous CO_2 escapes and, due to the rapid drop in pressure and

temperature, forms carbon dioxide snow. This snow, when compressed into blocks or cubes, us what we know as "dry ice." Dry ice, in solid form and at atmospheric pressure, volatilizes, remaining at -109°F until it has disappeared. It is excellent for certain refrigeration uses.

Because it will neither support combustion nor form explosive mixtures, CO_2 is one of the chief fire extinguishing agents in use today. It is also used for inflatable gear such as life rafts and vests, and as a propellant or expelling agent.

Carbonated soft drinks contain carbon dioxide dissolved in water and kept under pressure in the container. When this pressure is relieved, CO_2 bubbles will rise to the surface.

Small percentages of carbon dioxide will cause tiredness and perhaps headaches. Three percent in the air doubles breathing effort, and 5 percent causes panting. Eight percent causes marked distress and 10 percent causes unconsciousness very quickly.

Since CO_2, in addition to being heavier than air, is both invisible and odorless, it presents a particular hazard. It will tend to collect in low, unventilated places which might well be below decks on shipboard for instance. The fact is obvious that the more of any other gas, poisonous or not, that is present, the less breathable oxygen there will be present. Men going into these conditions or places, or left there, run the risk of suffocating to death.

Treatment of personnel exposed to CO_2 includes removal from the CO_2-laden atmosphere, artificial respiration (if necessary), administering oxygen, and keeping the patient warm and quiet.

The safety precautions to observe when entering spaces containing carbon dioxide gas are as follows:

1. Do not enter an area or compartment containing hazardous amounts of carbon dioxide without being equipped with a breathing mask and an independent supply of oxygen.

2. If this is not practicable, and the case is urgent, enter only when equipped with a life line and with an assistant standing by outside the area or compartment.

Oxygen

Oxygen is a colorless, odorless, tasteless gas that makes up about 21 percent of the atmosphere. Although oxygen is found in many compounds such as, water, limestone, sand, and iron ore, it occurs as free oxygen only in the atmosphere.

Probably to humans, the most important property of oxygen is that it is the element in the air that supports life. If the required amount of oxygen is not present in the atmosphere, it is not possible for people to live. In high altitude flying, or in confined spaces, it is necessary to supply air for breathing from some outside source. One of the important uses of oxygen, therefore, is to furnish a supply to persons who would otherwise face a lack of oxygen.

Another shipboard use for oxygen is for oxyacetylene welding. When mixtures of oxygen and acetylene burn, they furnish a very high heat which is easily controlled. This type of heat is also used to heat treat metals.

Oxygen is normally shipped in a gaseous state in cylinders and is one of two types, (1) aviators' breathing oxygen (99.5 percent pure oxygen) and (2) technical or industrial oxygen. The Navy buys only aviators' breathing oxygen. This not only simplifies the supply system but eliminates the possibility of industrial oxygen being charged into aviators' breathing apparatus. Industrial oxygen may have a small moisture content which would freeze at high altitudes.

While oxygen is itself nonflammable, it gives intensive support to combustion. If it should become mixed with hydrogen or with grease, it becomes highly explosive. No combustible material should ever be allowed to come into contact with compressed oxygen.

Oxygen plants are installed on all CVA's and in some other type ships. The method of producing oxygen will be discussed later in this chapter.

Nitrogen

Nitrogen (N_2) is considered to be an inert gas. It is not completely inert like helium or argon, for there are many nitrogen compounds such as the nitrates used in fertilizers and explosives. However, nitrogen is very slow to combine chemically with other elements under normal conditions. This is clearly seen when you consider that four-fifths of the atmosphere is nitrogen. Unlike oxygen, nitrogen, as a gas, does not support life or combustion, and causes no decomposition of most of the things with which it comes in contact. By chemical and

electrical processes it can, and is, taken from the air and combined with other substances. Such processes are known as "nitrogen-fixation."

In the Navy, nitrogen is used for pressure-operated mechanisms such as recoil systems, as an expellent in flame throwers, in optical instrument applications, for testing pipelines, and as a gas-blanket if required (as in atmospheric controlled furnaces), and for preservation packing. Nitrogen for naval use is pumped by a water-lubricated compressor and is specially dried. Nitrogen cannot be used for inert-gas shielded metal arc welding because the high temperatures involved can cause nitrogen to combine with other substances.

Nitrogen is slightly lighter than air, and, as indicated, is neither flammable nor explosive. It is not poisonous, but unless oxygen is mixed with it, it is an asphyxiant. Nitrogen gas is obtained by the fractional distillation of air. On aircraft carriers, nitrogen is a byproduct of the oxygen plant. The nitrogen is utilized extensively on these ships for maintaining an inert blanket over aviation fuel and other special fuels in their respective storage tanks.

The safety precautions for nitrogen are similar to those for liquid oxygen. However, since nitrogen (liquid or gas) does not support combustion, the precautions regarding exposure to sparks, open flame, and combustible materials do not apply.

Safety rules relative to the use of gaseous nitrogen are similar to those cited for other non-flammable, non-oxidizing, and non-toxic compressed gases. Nitrogen should not be discharged, in large quantities, into closed compartments unless adequate protection is provided.

CYLINDER DESIGN AND IDENTIFICATION

Gas cylinders are made of high quality steel. For high pressure gases, such as oxygen and hydrogen, cylinders are of seamless construction. For low pressure gases, such as acetylene, the cylinders may be welded or brazed. All cylinders are carefully tested at pressures above the maximum permissible charging pressure. Figure 16-19 shows the characteristics of commonly used cylinders.

Gas cylinders are substantially the same, except those for acetylene. Acetylene cylinders are completely filled with a porous material impregnated with acetone, which acts as a solvent; and are stubby, rather than slender, as shown in figure 16-20. All gas cylinders have safety devices either in the valve or in the shoulder or bottom of the cylinder, or in a combination of these places.

One type of safety device is the fusible plug, which may be described as a threaded hex head plug, having a center filled with a fusible metal. If the cylinder should be subjected to high temperatures, the fusible metal will melt, allowing the gas to vent to the atmosphere.

Unbacked safety devices with rupture disks consist of a perforated safety cap covering a safety port. The cap retains a frangible disk firmly over the safety port. Under excessive pressure, the safety disk ruptures, allowing the gas to escape through the ports.

Backed safety devices with rupture disks have a frangible disk supported by fusible metal (contained in the safety cap) blocking off escape ports. If the cylinder becomes heated above the melting point of the fusible metal, the pressure in the cylinder will increase and the frangible disk will rupture, venting the gas to the atmosphere.

To protect the valve, a threaded valve protection cap screws onto the cylinder neck ring.

Gas cylinders used by the Navy, Army, and Air Force carry certain standard identifying features in addition to markings required by the Interstate Commerce Commission. So much injury and damage can be, and has been caused by mistaking one gas cylinder for another, that a national program has been established to make it almost impossible to confuse cylinders. Under this program, the identifying features used by the Armed Forces consist of a color code for painting the cylinders, stenciling the name of the gas along two sides of the cylinder, and affixing two decalcomanias to the shoulder of each cylinder. The official color code for marking compressed gas cylinders is given in the current MIL-STD-101. The color coding is revised from time to time. In checking the cylinder color code, always be certain you have the latest revision including ALL page changes.

Navy-owned gas cylinders are identifi. . by indented serial numbers, proceeded and followed by the letters USN. Navy serial numbers are augmented by a designated letter preceeding the numerals. This letter identifies the cylinder in respect to the specific gas contained in that

SERVICE	CAPACITY [1]	WORKING PRESSURE	ICC SPEC.	DIMENSIONS (Approximate) DIAMETER	DIMENSIONS (Approximate) LENGTH (Add 6 inches for cap)	EMPTY WEIGHT (Approximate)	PERIODIC TEST REQUIRED	OUTLET CONNECTION
		p.s.i.		Inches	Inches	Pounds		Inches
Acetylene	10 cu. ft.	250	ICC8	4	14	11 2/	NO	3/8
	40 cu. ft.	250	ICC8	6	25	40 2/	NO	3/8
	50 cu. ft.	250	ICC8	7	26 - 1/4		NO	1
	225 cu. ft.	250	ICC8	12	36	130 - 134 2/	NO	1
Air	200 cu. ft.	1,800	ICC3A	9	51	110 - 115	Yes	3/4
Ammonia	100 lbs.	480	ICC3A	10 - 13	50 - 68	130 - 140	Yes	3/4 and 1
Argon	197 cu. ft.	1,800	ICC3A	9	51	110 - 115	Yes	3/4
Butane	100 lbs.	240 - 300	ICC4B	13 - 16	45 - 55	100 - 125	Yes	3/4
Carbon dioxide (storage)	50 lbs.	1,800 - 2,015	ICC3A	8 - 1/2	51	110 - 115	Yes	3/4
Carbon dioxide (fire extinguisher) 3/	do.	2,015	ICC3A	8 - 1/2	51	3/ 110	Yes	1
	35 lbs.	2,015	ICC3A	8 - 1/2	34	90	Yes	1
	15 lbs.	2,015	ICC3A	6 - 1/4	26	35	Yes	1
Carboxide	30 lbs.	1,800 - 2,015	ICC3A	8 - 1/2	26	65 - 70	Yes	3/4
	60 lbs.	1,800 - 2,015	ICC3A	8 - 1/2	51	100 - 115	Yes	3/4
Chlorine	30 lbs.	480	ICC3A	6 - 8	27 - 30	30 - 35	Yes	3/4
	120 lbs.	480	ICC3A	9 - 12	34 - 44	85 - 90	Yes	3/4
	150 lbs.	480	ICC3A	10 - 13	50 - 68	130 - 135	Yes	3/4
Helium	200 cu. ft.	2015	ICC3A	9	51	110 - 115	Yes	3/4
Nitrogen	184 cu. ft.	1800	ICC3A	9	51	110 - 115	Yes	3/4
Oxygen	200 cu. ft.	1800	ICC3A	9	51	110 - 115	Yes	3/4
	23.3 cu. ft.	2015	ICC3A	5 - 3/8	18	19	Yes	3/4
	38.4 cu. ft.	2015	ICC3A	7	19	31	Yes	3/4
Refrigerants 122, etc.	10 lbs.	300	ICC4B	4-1/2-5-1/2	14 - 16	13 - 15	Yes	3/4
	50 lbs.	300	ICC4B	7-1/2-8-1/2	27 - 29	27 - 30	Yes	3/4

1/ Where capacities are expressed in cubic feet, the volumes shown are those of the gas after withdrawal from the cylinder at atmospheric pressure and normal room temperature.

2/ Empty weight is normally stamped on the shoulder of the cylinders.

3/ For complete information on fire extinguisher carbon dioxide cylinders, see chapter 9930. Actual weights, charged and empty, will be found stamped on cylinder valve.

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Figure 16-19.—Characteristics of commonly used cylinders.

specific cylinder. The following are examples of serial numbers.

1. For an oxygen cylinder

U U
SX618793S
N N

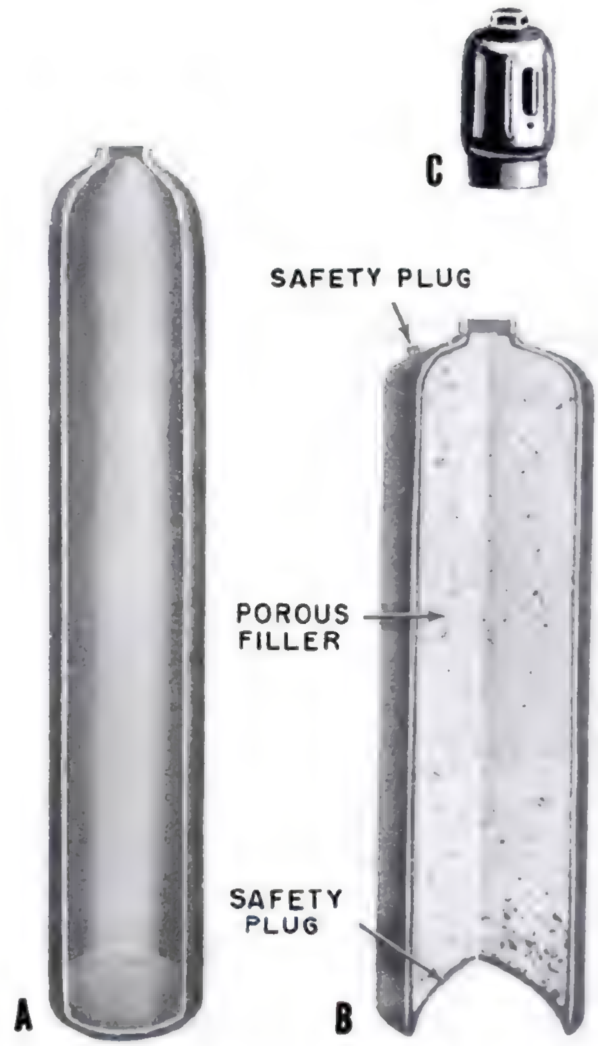
2. For an acetylene cylinder

U U
SA54687S
N N

In the first example, the letter "X" identifies the cylinder as one containing oxygen. In the second example, the letter "A" identifies the cylinder as an acetylene cylinder. The LETTERS assigned to gases are for identification purposes only, they have no consistent connection with spelling of a gas name of CHEMICAL SYMBOLS for gases. The acetylene symbol is C_2H_2, and for oxygen the correct chemical symbol is O_2.

If the camouflage scheme of a ship is adversely affected by the cylinder colors, canvas covers painted with the camouflage colors shall be put over the cylinders.

Shatterproof cylinders shall be stenciled in two locations with the phrase "Non-Shat" placed longitudinally and at a 90° angle from titles. Letters shall be black or white and approximately 1 inch in size.



47.163
Figure 16-20.—Cutaway view of compressed gas cylinders. A. Oxygen cylinder. B. Acetylene. C. Valve protection cap.

OXYGEN-NITROGEN PRODUCING PLANTS

Oxygen and nitrogen are produced aboard some ships, mostly CVA's. Only graduates of the Compressed Gases School (or men working under their direct supervision) are allowed to operate the oxygen-nitrogen plants. This training manual does not go into detail concerning oxygen-nitrogen plants, but merely explains the basic process of generating oxygen and nitrogen.

Oxygen can be produced by chemical or physical processes. Chemically, oxygen can be produced in a number of ways by releasing it from different compounds. For large-scale production, however, oxygen is produced by the physical process of distilling liquid air.

Atmospheric air is a mixture of oxygen and nitrogen and is therefore a convenient and inexhaustable source of both of these gases. The problem is to separate them simply and economically.

Liquid mixtures can be separated by heating. The component having the lowest boiling point leaves the mixture before the components with higher boiling points are heated enough to boil off. This process is known as DISTILLATION. By first liquefying air, the process of distillation can be used to separate oxygen from nitrogen. Nitrogen has a lower boiling point than oxygen, and therefore will leave the mixture first.

In the liquid air process for producing oxygen, air is cooled until it becomes a liquid. The

liquid is then distilled—that is, the nitrogen is boiled off as a gas, while the oxygen remains as a liquid.

The liquid oxygen can then be drained off to a storage tank, and when ready for use, converted to a gas.

Liquefying Air

At atmosphere pressure, the boiling point of oxygen is -297°F, and that of nitrogen is -321°F. You can readily see that a great amount of heat must be removed from air in order to liquefy it.

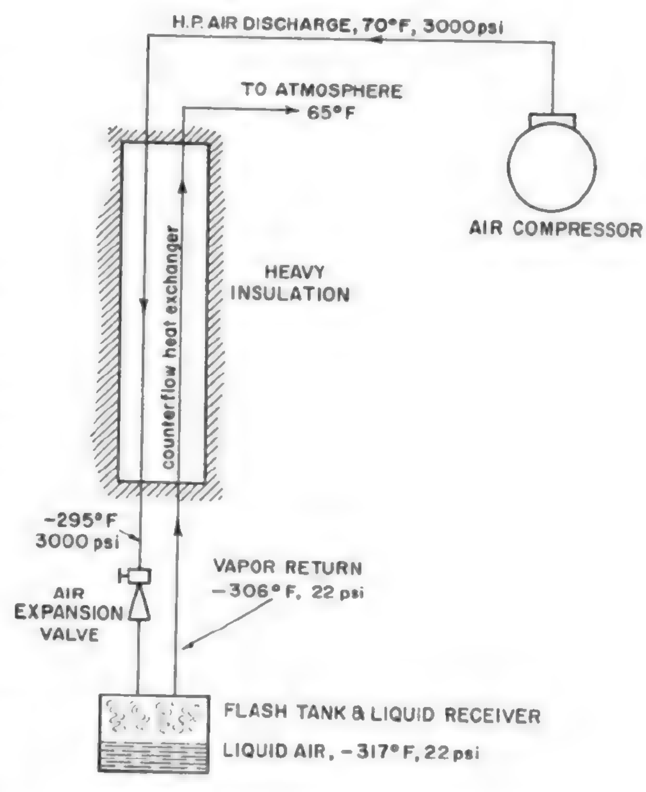
A temperature of -297°F may be hard to imagine. Ice feels very cold to the touch; it melts at 32°F. The North Pole is very cold, yet the air there is rarely below -70°F or -80°F. You can see how much colder air must be in order to liquefy.

There is a natural tendency to think of a boiling point as applied only to water. The boiling point of a substance is the temperature at which it turns from a liquid to a gas. At a given pressure the boiling point is a fixed temperature for any one material. Pressure always affects the boiling point. A good example of this temperature-pressure relationship is that water or any other liquid will boil at lower temperatures on high mountains than at sea level.

Since we make use of differences in boiling points to separate oxygen from the other constituents of air, it follows that the big job, outside of the actual distillation itself, is to liquefy air. To do this, heat must be removed from the air. You will remember that a change in the pressure of a gas is directly proportional to a change in temperature. Therefore, it follows that if you expand a gas, or lower its pressure, the temperature of the gas will drop. This fact is made use of in lowering the temperature of air in order to liquefy it. Air is compressed in stages, cooled, and then suddenly expanded. This drops the temperature below the boiling point of air.

Atmospheric air, at sea level, is composed of nine gases. For practical purposes, let us assume air to be a mixture of two gases: nitrogen, 78 percent, and oxygen, 21 percent. The remaining gases we will refer to as rare gases. These gases, with the exception of carbon dioxide (CO_2) will cause little trouble in the operation of an oxygen-nitrogen plant. CO_2 has to be removed from the air stream as it will solidify at -109°F. When CO_2 becomes a solid, it can block the passage of air and reduce or stop the plant production. Solid particles of CO_2, if allowed to carry over into the oxygen, would lower the purity of the oxygen below the required 99.5 percent.

Figure 16-21 shows a simple, high pressure liquid air plant. The temperatures and pressures are only approximate values and are for purposes of explanation only. The main components of the high pressure liquid air plant are: (1) high pressure air compressor, (2) counterflow heat exchanger, (3) air expansion valve, and (4) liquid air receiver or flash tank. The expansion valve plays a major role in the liquefaction process. To understand the function of this valve, you have only to know that air is cooled when allowed to expand from a high pressure area to a low pressure area. In figure 16-21, air is expanded from 3000 psi down to 22 psi and the temperature drops from 70°F to -317°F. The expansion valve provides the fundamental source of cooling.



47.164
Figure 16-21.—Simple oxygen plant.

The flow of air must be continuous, but for simplicity of explanation we will consider the air flow as the first, second, and third pounds of air entering the plant. The air is discharged from the compressor at 3000 psi. Trace the air flow on figure 16-21. The first pound of air enters the high pressure side of the counterflow heat exchanger at about 70°F. It leaves the heat exchanger at the same temperature, for there is no return flow in the low pressure side of the heat exchanger with which it can exchange heat. The first pound of air blows through the expansion valve and its pressure is reduced to 22 psi and its temperature drops a small amount. The air continues down into the flash tank, out, and back through the low pressure side of the heat exchanger.

Suppose now that the second pound of air, at high pressure, is just starting down the high pressure side of the heat exchanger, as the first pound is passing up the low pressure side. The two pounds of air will be at different temperatures, so a heat transfer will take place. The first pound of air, being cooler than the second pound, will cool the second pound. Thus the second pound of air will arrive at the expansion valve cooler than the first pound. The second pound of air will pass through the expansion valve and be cooled to a lower temperature than was the first pound.

The second pound of air will pass through the flash tank and up through the low pressure side of the heat exchanger, where it will cool the third pound of air which is now entering the heat exchanger. The third pound of air will pass through the expansion valve and be cooled to a lower temperature than the second pound because it arrived at the expansion valve at a lower temperature and went through the same pressure drop.

This process goes on and on until the plant reaches a temperature low enough for the air to liquefy as it blows through the expansion valve (approximately -317°F).

With this process, about 9 percent of the air entering the plant will become useable liquid oxygen. The oxygen yield can be increased to 21 percent by the use of mechanical refrigeration. As previously explained, the lower the temperature of the air entering the expansion valve the lower will be the temperature of the air leaving the expansion valve. The mechanical refrigeration is not essential, but is used only to increase the yield of the plant.

Separating Oxygen and Nitrogen

To more fully understand the distillation process which separates the oxygen from the nitrogen, we will first consider a container of water being heated. In time vapor (steam) will rise from the container. The vapor will be of the same composition as the water remaining in the container. The vapor is the gaseous phase and the water is the liquid phase.

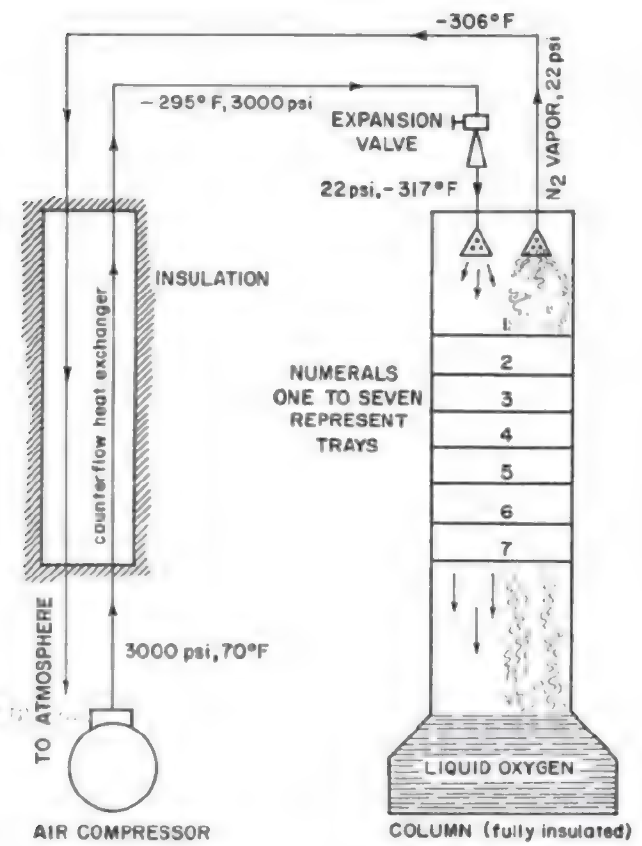
Let us now consider a container of liquid air instead of water. As heat is applied, a vapor is driven off. The vapor will have a composition of 5 percent oxygen and 95 percent nitrogen. If the boiling is continued, the remaining liquid will become richer and richer in oxygen.

At the present time, all liquid oxygen plants used aboard ship operate by the distillation process. The liquid air leaves the expansion valve and enters at the top of a distilling column (fig. 16-22) and begins to fall down through a series of trays. The column is a towerlike affair with a coil in the bottom. Above the coil are tiers of porous trays (fig. 16-23). The liquid air comes into contact with the warmer vapor rising off the liquid product collected in the bottom of the column. This rising vapor gets richer in nitrogen, because the nitrogen, having a lower boiling point, will boil off first. The downflowing liquid will become richer in oxygen as the nitrogen continues to boil off. The liquid entering the top of the column is a mixture of oxygen and nitrogen and one part of the mixture (nitrogen) is being released by boiling. The part of the mixture remaining in the bottom of the column is oxygen. This is the process going on inside a simple column. In a plant of this type, liquid oxygen can be drawn off from the bottom of the column and gaseous nitrogen released (through the heat exchanger) to the atmosphere.

Some plants are designed to produce pure (99.5%) liquid oxygen and pure gaseous nitrogen. In this type of plant, two columns are used. The two products, liquid oxygen and gaseous nitrogen, are drawn off and stored until ready for use. Details of this type of plant will not be given in this training manual.

SAFETY PRECAUTIONS FOR INDUSTRIAL GASES

All compressed gases are hazardous. Many detailed precautions could be set down regarding

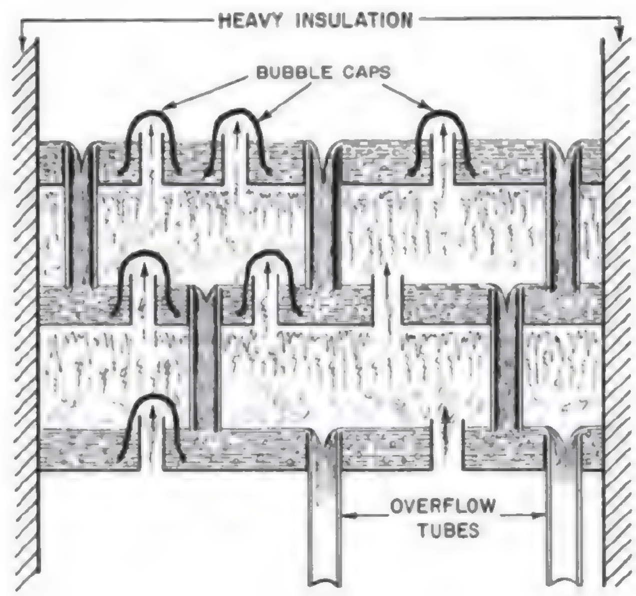


47.165
Figure 16-22.—Oxygen plant showing column and position of trays.

handling, storing, and transporting these gases. Make certain that all special precautions relative to the particular gas being used are observed. Some of the more important precautions to be observed in handling all industrial gases are:

1. See that all required gas or chemical analyses are carefully made and recorded.
2. Make certain that all plant adjustments are made in accordance with these analyses.
3. Constantly inspect for leaks, and repair immediately any leaks located.
4. Watch all pressure and temperature gages with extreme care.
5. Never permit any flames, sparks, or flammable material in the plant.

In HANDLING THE COMPRESSED GASES, never use gas from a cylinder except through a



47.166
Figure 16-23.—Porous bubbler trays.

pressure regulator with its adjustment screw properly set.

1. Open the cylinders by hand, never with hammers or wrenches.
2. Crack open the valve 1/4 turn and close, before connecting the pressure regulator; do not open the valve near sparks or other sources of ignition.
3. Do not let gas enter pressure regulators suddenly.
4. Open valves full when cylinder is in use (only 1 1/4 turns for acetylene valves).
5. Never tamper with safety devices; never force-fit any of the connections.
6. Close valves which leak at the stem; release gas to outdoor atmosphere if safety device leaks.
7. When referring to a particular gas always use its identifying name—never refer to it as just "gas."
8. Make sure hoses and fittings are always tight; do not interchange fittings or hoses with similar equipment for other gases.
9. Never tighten an adjustment nut to stop a leak before first closing the valve and releasing any pressure in the system.
10. Close the valves and replace outlet caps when cylinders are not in use.

11. Before removing pressure regulators, close the valve and release all gas from the regulator.

In HANDLING THE GAS CYLINDERS, use the cylinders only for the gas for which they are intended.

1. Never remove numbers or any other markings from cylinders.
2. Do not use cylinders for rollers or any other nonstandard purpose.
3. Never handle cylinders roughly or use them where they can be damaged by falling objects, etc.; always handle all cylinders as though full (unknown pressure remaining may otherwise cause accidents).
4. Do not lift cylinders by valve caps but provide carrying devices—never drag or slide.
5. In promoting more rapid discharge, never immerse more than 20 percent of the cylinder surface area, and never immerse in water over 125°F (fusible plugs will otherwise soften or melt).
6. Never store near flammable material (oil, gasoline, waste, etc.), in damp locations, near live wires, near corrosive chemicals or fumes, near heaters, or near any other gas.
7. Erect fire-resistant partitions between flammable and nonflammable gas cylinders.
8. Store gas cylinders (except ammonia) upright.
9. Make sure storage rooms are ventilated to prevent accumulation of an explosive or otherwise harmful concentration of gas.
10. Mark empty cylinders "empty" or "MT," and segregate them from full cylinders.

CHAPTER 17

ENGINEERING CASUALTY CONTROL

Casualty prevention is the most effective form of casualty control. Engineering casualty control reaches its maximum efficiency by a combination of sound design, careful continued inspections, thorough plant maintenance including preventive maintenance, and by effective personnel organization and training. Casualty control effectiveness may determine the ship's ability to fulfill its prescribed mission. Regardless of the ship's inherent resistance to damage, her survival depends upon prompt and correct control action being taken when casualties occur. It is of vital importance, therefore, that you be fully aware of and trained for whatever action you may be called upon to perform in any possible casualty situation. Casualty control training must be a continuous step-by-step procedure with frequent refresher drills.

CONTROL OF CASUALTIES

Engineering casualty control is concerned with the prevention, minimization, and correction of the effects of operational and battle casualties to engineering space machinery, related machinery outside of engineering spaces, and the piping installations relative to the various pieces of machinery. The mission of engineering department personnel is the maintenance of all engineering services in a state of maximum reliability under all conditions. Failure to provide all normal services will affect a ship's ability to function effectively as a fighting unit, either directly by reducing its military function, or indirectly by reducing habitability and efficiency.

Work involved in the HANDLING OF ENGINEERING CASUALTIES can be divided into three general phases:

1. Immediate action to prevent further damage.
2. Emergency restoration of service(s) interrupted by the casualty.
3. Repairs which completely restore damaged machinery, plants, or systems to their original condition.

To perform your casualty control job well, you must master the operation of the equipment at your normal duty station and at your battle station. The Engineering Operation and Casualty Control Manual, your ship's Damage Control Book, the Ship's Organization Book, the manufacturer's emergency instructions for the equipment or systems on your GENERAL QUARTERS STATION, and the ship's Damage Control Bills are your primary sources of instruction for handling any engineering casualty in addition to maintaining the over-all damage resistance of your ship. These publications may vary on different ships, but in all instances they present the organization and procedures to be followed in event of engineering casualties, damage to the ship, or other emergency conditions.

PREVENTIVE MAINTENANCE

One of the principal factors which influence the effectiveness of casualty control is preventive maintenance. Preventive inspection, test, and maintenance, are vital to successful casualty control; these activities minimize the occurrence of casualties caused by material failures. Continuous detailed inspection procedures are necessary to discover worn or partly damaged parts which may fail at a critical time, and to eliminate the conditions, such as maladjustment, improper lubrication, corrosion, erosion, and other enemies of machinery reliability that could lead to early failure.

The inspection, test, and maintenance called for in the 3-M System must be conscientiously performed since they are based on the known requirements of preventive maintenance.

SYMPTOMS OF OPERATIONAL CASUALTIES

You must be on the alert at all times to detect even the most minor sign of faulty operation of machinery. Particular and continuous attention must be paid to the following symptoms of malfunctioning of machinery:

1. Unusual noises.
2. Vibrations.
3. Abnormal temperatures.
4. Abnormal pressures.
5. Abnormal operating speeds.
6. Leakage from systems or associated equipment.

You should become thoroughly familiar with the normal temperatures, pressures, and speeds of equipment specified for each condition of operation; departures from normal will then be readily apparent. It must not be assumed that an abnormal reading on a gage, or on any other instrument indicating operating conditions of machinery, is caused by an error in the instrument. Each such case should be investigated to establish fully the cause of the abnormal reading. Either the substitution of a spare instrument or a calibration test will quickly show whether an instrument error exists. Abnormal readings which are not caused by faulty instruments must be traced to their source, if preventive maintenance is to be effective. Some specific examples of advance warning of ultimate failure are outlined in the following paragraphs.

Because of the safety factor commonly incorporated in pumps and similar equipment, considerable loss of capacity can occur before any external evidence of trouble is readily apparent. In pressure governor controlled equipment, changes in operating speeds from normal for the existing load should be viewed with suspicion. Variations from normal in chest pressures, lubricating oil temperatures, and system pressures indicate either inefficient operation or poor condition of the machinery. Where a material failure occurs in any unit, a prompt inspection should be made of all similar units to determine whether they are subject to the same type of failure. Prompt inspection may eliminate a wave of similar casualties.

Abnormal wear, fatigue, erosion, or corrosion of a part may indicate a failure to operate the equipment within its designed limits of loading, velocity, and lubrication; or it may indicate a design or material deficiency. If any of these symptoms have appeared, special inspections to detect damage should be undertaken as a routine matter, unless action can be taken which will ensure that such a condition will not recur.

Strict attention must be paid to the proper lubrication of all equipment; this will include frequent inspection and sampling to determine that the correct quantity of the proper lubricant is in each unit. It is good practice to take daily samples of lubricating oil from all auxiliaries. Such samples should be allowed to stand long enough for any water to settle. Where auxiliaries have been idle for several hours, particularly overnight, a sample should be drained from the lowest part of the oil sump. All settled water must be drained from the sump and the oil level must be brought back to normal by adding fresh oil. An unusual quantity of fresh water in the oil is normally indicative of either poorly fitted or worn carbon packing on the turbine-driven pumps.

Salt water may enter the oil from the salt water pump glands, from the salt water cooled oil coolers, or from salt water dripping or spraying on the unit. The presence of salt water in the oil can be detected by drawing off a sample of oil and allowing it to settle. Because of its corrosive effects, salt water in the lubricating oil is far more dangerous to a unit than an equal quantity of fresh water. Salt water is particularly harmful to units with oil-lubricated ball bearings. When units with oil-lubricated ball bearings are found to be subject to salt water contamination of the lubricating oil, it is essential that the oil be drained as soon as possible, that the bearings and sump be flushed thoroughly, and that the unit be refilled with fresh oil.

GENERAL PROCEDURES FOR CONTROL OF ENGINEERING CASUALTIES

The importance of engineering casualty control cannot be taken lightly. Failure of any of the ship's normal services immediately reduces the ship's resistance to damage, and impairs its ability to function effectively as either a fighting or auxiliary unit. The effects of engineering casualties are both direct and indirect. Directly, the casualties reduce the ship's mobility, offensive power, defensive power,

its ability to control fire, flooding, hull, and armament damage. Indirectly, the casualties reduce the ship's habitability and, thereby, lower the morale and efficiency of personnel.

It is quite easy for a single damaged unit in a machinery plant to disable the entire plant. A leaking condenser, for example, may disable both the boilers and the turbines. A damaged lube oil line or pump, and the resulting loss of pressure, can also quickly damage the turbine bearings and reduction gear bearings. Prompt remedial action must always be taken as soon as the casualty occurs.

The speed with which corrective action is undertaken in an engineering casualty is frequently of paramount importance. This is particularly true when such casualties affect propulsion power, steering, and electrical power generation and distribution. If casualties associated with these functions are allowed to become cumulative, they may lead to serious damage to the engineering installation—damage which often cannot be repaired without loss of the ship's operating ability. Where the risk of developing permanent damage exists, the commanding officer has the responsibility of deciding whether to continue operation of the equipment under casualty conditions; such action can be justified only where the risk of greater damage, or even loss of the ship, might be incurred as a result of immediately securing the affected unit. For example, an entire plant might be operated with abnormal salinity present if such operation were necessary to enable the ship to steam clear of an area of possible enemy attack. However, all possible steps must be taken to shorten such a period of hazardous operation. It is reemphasized that whenever there is no probability of greater risk, the proper procedure is to secure the malfunctioning unit as quickly as possible, even though considerable disturbance to the ship's operations may result.

Although speed in controlling a casualty is essential, action should never be taken without accurate information; otherwise the casualty may be mishandled, and further damage to the machinery may result. Cross-connecting an intact plant with a partly damaged one must be delayed until it is certain that such action will not jeopardize the intact one.

The discussion of engineroom casualties in this chapter is intended to give you a general idea of how casualties should be handled. For further information on casualty control, study the Ship's Casualty Control Manual and the Engineering Department Instructions for your ship.

Most of the casualties discussed in this chapter are treated in a step-by-step way. In handling actual casualties, the steps may have to be modified. Different circumstances may require a different sequence of steps for control of a casualty. Also, in handling a real casualty you may have to see that several steps are performed at the same time. You should learn the steps for controlling casualties in the order in which they are given, but do not overlook the fact that steps may have to be performed simultaneously.

ENGINEROOM CASUALTIES

For each class of ship, the type commander formulates engineering casualty procedures which are applicable to the specific type of engineering plant. However, the Naval Ship Systems Command recommends general procedures for the control of typical engineroom casualties. As a Machinist's Mate, you are required to have a thorough knowledge of the action to be taken for a specific casualty.

LUBRICATING OIL CASUALTIES

Even a momentary loss of flow of lubricating oil to the bearings of a machine will result in localized overheating and probably in slight wiping of one or more bearings. Damage can be prevented or minimized by stopping the shaft and quickly restoring the flow of lubricating oil. Continued operation with wiped bearings will cause serious derangement to the entire unit. The important lubricating oil casualties that may arise are discussed in the paragraphs which follow.

Loss of or Low Lubricating Oil Pressure

SYMPTOMS:

1. High lubricating oil pump discharge pressure, in conjunction with low bearing pressure.
2. Other indications of loss of lubricating oil service.

CAUSES:

1. Stopped up lubricating oil line.
2. Clogged lubricating oil strainer.
3. Malfunction of pump or service lines.
4. Loss of oil in main sump.
5. Failure of the operating pump, coupled with failure of the standby pump to start.
6. Failure of power supply, steam or electric, to main lubricating oil pumps due to an operational casualty or damage to boilers, steam lines, or electric equipment.

ACTION TO BE TAKEN:

The loss of, or low lubricating oil pressure, must be considered as a serious casualty because of the possibility of progress toward a casualty of major, if not vital, dimensions. Operating personnel must use utmost care and thoroughness in performing all maintenance inspections and procedures which could prevent casualties to the lubricating oil system.

1. Notify Main Engine Control of the casualty and keep them informed.
2. Upon failure of standby pump to cut in on reduced oil pressure, or other indication of loss of lubricating oil service, STOP THE AFFECTED SHAFT and endeavor to regain lubricating oil pressure.
3. When steam pressure is available, close the throttle in use and stop the shaft by use of the astern throttle, or vice versa, if backing down. Engage and lock the jacking gear.
4. When steam and lubricating oil pressures are lost simultaneously in one engine room during split-plant operation, and the plant cannot be immediately cross-connected, take way off the ship by backing on the other engine.
5. If plant cannot be cross-connected, and ship cannot be stopped, stop and lock the affected shaft as soon as steam is available.
6. Inspect all bearings and ascertain which have been overheated.
7. Secure gland sealing steam and main air ejectors to minimize rotor distortion if shaft is to remain locked for an appreciable length of time.
8. Shift and clean lubricating oil strainer basket in use at the time of the casualty. Determine if flakes of metal are present in basket.
9. Start lubricating oil purifier if it is not in use.
10. When oil pressure is restored, circulate oil until bearings are cool.
11. Take bearing wear micrometer readings of all bearings and axial clearances where means are provided. A good micrometer reading is NOT a definite indication that no damage has occurred. Build-up of wiped bearing metal may hold the shaft in its proper position and give a false indication of the condition of the bearing.
12. Proceed with removal and inspection of bearings.
13. Main Engine Control should:
    a. Notify bridge of casualty, action being taken and estimated time required to make repairs.
    b. Request permission to alter speed, or stop the ship, as necessary.
    c. Direct engine room to cross-connect systems as necessary.

In some ships, each propulsion shaft lubricating oil service system is supplied by:

1. Shaft or gear driven pump. (Normal Service Pump.)
2. Turbine driven standby pump.
3. Motor driven emergency lube oil pump-capacity for full astern shaft RPM or 1/2 capacity of turbine driven standby pump whichever is greater. In ships provided with the gravity flow lubricating oil system, shift to forced lubrication immediately if leak is in gravity flow.

POSSIBLE ASSOCIATED CASUALTIES:

The information contained in this paragraph, pertains to steam driven ships. It does not pertain to Diesel, gas-turbine, specific ships, research and development designs, or nuclear driven ships.

1. Permanent damage to shafts.
2. Destruction of bearings.
3. Damage caused by excessive vibration of shafts.

Cooler Tube Carries Away

ACTION TO BE TAKEN:

1. Notify Main Engine Control of casualty and keep them informed.
2. Main Engine Control Action:
    a. Notify bridge of casualty, action being taken, and estimated time to make repairs.

b. Request permission to adjust speed as necessary.

c. Notify bridge that the ship leaves an oil-slick under certain conditions.

3. When permissible to reduce speed:

a. By-pass cooler. (When applicable)

b. Operate at speeds below the critical bearing temperature.

c. Replenish oil through purifier from storage tank to sump to restore the working level.

4. When not permissible to reduce speed sufficiently, oil leak minor and adequate supply of oil on board:

a. Increase the lubricating oil pressure if necessary so that oil will leak into the water side of the cooler.

b. Pump make-up oil into the sump tank.

c. Water from fire-main directed to outside of oil line will have some cooling effect.

d. Take continuous sounding on sump tank.

5. When not permissible to reduce speed, major oil leak:

a. Secure inlet and outlet and drain sea water side of lube oil cooler.

b. Apply artificial cooling to shell of lube oil cooler.

c. Sound sumps frequently, keep close check on oil level.

NOTE: Not all ships are provided with a means of by-passing a lube-oil cooler; and ships have more than one cooler that can be placed in service.

Lubricating Oil Leak
Into Engineroom

CAUSES:

1. Rupture or failure of piping, valves, or associated components of lubricating oil system.

2. Malfunction, or breakage of mechanical components of lubricating oil system.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.

2. Request permission from Main Engine Control to secure engine.

3. Plug, patch, or renew leaking piping.

4. Repair or readjust malfunctioning pump, filter, or other component.

5. Remove fire-hazards to prevent possible fires.

6. Inspect oil level in sump, and replenish make-up lubricating oil through the purifier should time permit, and as necessary.

7. Reduce ship's speed as necessary to make repairs.

8. Main Engine Control should:

a. Notify bridge of casualty, action being taken and estimate of time required to make repairs.

b. Request permission to adjust speed as necessary.

POSSIBLE ADDITIONAL CASUALTIES:

1. Fire hazard.

2. Mechanical failure of bearings.

Excessive Oil Pump
Discharge Pressure

SYMPTOMS:

1. Presence of the casualty is the symptom.

2. Low bearing oil pressure.

CAUSES:

1. Restriction in the lubricating oil system.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.

2. Check strainers.

3. Should the shifting of strainers fail to reduce pressure, inspect all other parts of the lubricating oil system for restrictions, and remove such whenever located.

4. Investigate the constant pressure pump governor for proper operation. Make adjustment or repairs as necessary.

5. Inspect strainer and all parts of the lubricating oil system for restrictions of oil flow.

6. Check the lubricating oil pressure regulator valve to determine if jammed. If so, the by-pass around the valve is to be used as necessary to maintain in normal range.

7. High lubricating oil discharge pressure, resulting from a restriction in the system, will

be accompanied by low bearing oil pressure, and must be handled as loss of lubricating oil pressure.

LOSS OF VACUUM

The casualty is the symptom and the condition.

CAUSES:

1. Excessive air leakage into the vacuum system:
   a. Insufficient gland sealing steam.
   b. Open vent valve on idle condensate pump.
   c. Open loop seal filling valve.
   d. Drain tank float valve stuck in the open position.
   e. Make-up feed valve open to empty feed bottom.
   f. Leakage of flanges, fittings or valve stem packing.
   g. Broken or loose hot-well gage glass.
   h. Astern throttle and by-pass leaking.
   i. Leakage of air through condensate pump stuffing box due to lack of sealing water or poor condition of packing.

2. Malfunctioning of air removal equipment:

   a. Insufficient steam to air ejectors.
   b. Foreign material lodge in the air ejector nozzles.
   c. Improper drainage at steam side at the air ejector condensers.
   d. When vacuum is lowered over a period of time (slowly):

      (1) Erosion of the air ejector nozzles.
      (2) Leakage between air ejector nozzle threads and housing.

   e. Clogged strainers in the air ejector steam supply line.
   f. Steam chest gaskets of nozzle rings of injector could be of incorrect thickness.

3. Flooding at condenser:

   a. Low speed of condensate pump, indicating malfunctioning of the pump speed limiting governor.
   b. Condensate pump air bound, due to the vent connection from the first stage being closed or not in full open position.
   c. Insufficient pumps in service.
   d. Excessive wearing of ring clearances.

4. Insufficient flow of circulatory water:

   a. Improper adjustment of overboard discharge valve, or main injector valve is closed.
   b. Inadequate speed of main circulating pump, which must be used at forward speeds of less than specified rate, or main circulator suction valve is in closed position.
   c. Plugged tubes, due to mud, shells, small fish or kelp being trapped against strainer bars, or in the intake-water chest.
   d. Flapper valve stuck in open position or closed position.
   e. Air trapped in condenser.

5. High injection temperature:

   a. Basically, the injection temperature limits the maximum vacuum (maximum absolute pressure) obtainable in a specific plant, assuming the condenser, associated equipment and piping under vacuum to be clean and properly operated.
   b. Dirty condenser, steam side.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Investigate and determine the cause of loss of vacuum.
3. Properly position all valves found to be improperly positioned.
4. Take down, clean, and flush out components found to be clogged.

NOTE: When a partial loss of vacuum occurs on a propulsion turbine during normal underway steam conditions, including full power, and the situation permits (other than combat or alongside fueling), immediately slow engine to compensate for loss of vacuum as follows: to 25''-2/3 speed; 20''-1/3 speed; 15'' (or less)-stop.

5. Detailed courses of action to be taken in the several above listed causes should be controlled by manufacturer's instructions and operating experience.

6. Main Control shall:

   a. Notify bridge of casualty, action being taken, and an estimate of the time required to correct the condition.
   b. Request adjustment of speed as necessary.

LOSS OF STEAM PRESSURE IN THE ENGINE ROOM

SYMPTOMS:

1. Steam pressure gage registers below normal operational pressure.
2. Gradual or immediate slow down of engines and components.
3. Many others, too numerous to list here, but quite obvious to the experienced engineering watch stander.

CAUSES:

1. Boiler room casualty.
2. Damage or malfunction of steam supply system.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Close the main throttle to prevent the auxiliary steam pressure from dropping below 85 percent of rated pressure and possible loss of the boiler(s) from the line. Trip the turbo-generator(s) from the line if auxiliary steam pressure continues to fall below 75 percent of rated pressure.
3. If the electrical load is split, the bus-tie between the two main switchboards must be closed immediately, until a supply of steam is available to the turbo-generator from the other plant.
4. Open both auxiliary cross-connection valves.
5. Open main and turbo-generator steam cross-connections.
6. Secure boiler stop valves.
7. Shift to electric auxiliaries as required.
8. Main Engine Control shall:

   a. Notify bridge of casualty, action being taken, and an estimate of the time required to correct the condition.
   b. Request permission to alter speed as necessary.

LOSS OF MAIN FEED PRESSURE

SYMPTOMS:

1. Gradual or sudden drop in boiler feed-water level indicator.
2. Boiler feed water pumps fail to function properly, noisy, racing, or stop.
3. Receipt of information that the feed water system has been damaged.

CAUSES:

1. Malfunction of machinery components.
2. Damage to feed water supply piping or stowage.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed of the situation.
2. Increase feed pressure with emergency feed pump cold suction, and close recirculating valve.
3. Open the steam throttle valve to a wider position.
4. Check the discharge pressure of main feed pumps and booster pumps.
5. Check water level in deaerating feed tank, and pressure of deaerating feed tank.
6. Check auxiliary exhaust pressure.
7. Inspect feed check-valves on idle boiler.
8. Check the operation of the constant pressure governor on the feed pump.
9. If unable to maintain water level, carry out low water procedure.
10. Request permission from Main Engine Control to open feed cross-connecting valve.
11. Notify Main Engine Control of method of feed water being taken, either main or emergency.
12. Main Engine Control must inform the bridge of the casualty action being taken, estimated time to make repairs or corrections, and request that the ship's speed be adjusted to conform with limitations of boilers.

POSSIBLE ADDITIONAL CASUALTIES:

1. Securing of boiler.
2. Loss of auxiliary steam pressure and steam-driven auxiliaries.
3. Loss of electric power and electric-driven auxiliaries.
4. Low or loss of lube oil pressure.
5. Loss of vacuum.
6. Loss of auxiliary exhaust.

LEAK IN CONDENSER

SYMPTOMS:

1. Excessive, or sudden release of steam, water spray, of flowing water from condenser.

CAUSES:

1. Corrosion of condenser tubes.
2. Damage from shock or excessive vibration.
3. Excessive pressure.

ACTION TO BE TAKEN:—Leaks which are not of sufficient magnitude to prevent continued operation when the estimated time of arrival in port is less than 24 hours:

1. Notify Main Engine Control and keep them informed.
2. Isolate the condensate system.
3. Limit the number of boilers on the engine involved.
4. Blow-down the boiler(s) as necessary to keep the feed water salinity within the specified limit.

When leaks are of sufficient magnitude to require immediate shutdown in operation:

1. Notify Main Engine Control, and keep them informed. Request permission to stop engine and secure affected plant.
2. Stop engine and secure affected plant.
3. Shift drains, auxiliary exhaust, and turbo-generator exhaust to the auxiliary condenser.
4. Continue the main lubrication oil system in operation, and proceed using other engine.
5. Inspect and test the condenser and plug leaking tube(s).
6. Main Engine Control shall:

    a. Notify bridge of casualty, action being taken, and an estimated time required to correct the condition.
    b. Request permission to adjust speed as necessary.

LOSS OF CIRCULATING WATER

SYMPTOMS:

1. Low sea water pressure indicated on pressure gage.
2. Fresh water cooling water and lubrication oil temperatures will rise above normal.

CAUSES:

1. Sea water pump failure.
2. Sea chest and/or strainer obstructed.
3. Pump air bound.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Notify bridge.
3. Reduce load and/or speed of engine, preventing overheating.
4. Cut in emergency sea water cooling from fire main.
5. Check operation and vent sea water cooling pump.
6. Check and clean sea water strainer.
7. Steam out sea chest if obstructed.

ASSOCIATED CASUALTIES:

Overheating of engine.

RUPTURE IN CIRCULATING WATER SERVICE PIPING

The casualty is the symptom and the condition.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Secure cut-off valves nearest to both sides of the rupture.
3. Plug or repair damaged piping.
4. Rig hose jumpers across or cross-connect around ruptured piping section, to provide cooling water to machinery components which require this cooling feature.

DEAERATING FEED TANK CASUALTIES

During normal operation, the only control necessary for operating a deaerating feed tank is maintaining the proper water level. Overfilling the deaerating feed tank may upset the steam-water balance and cool the water to such an extent that ineffective deaeration will occur. Overfilling the deaerating feed tank also wastes heat and fuel.

The deaerating feed tank casualties which are of importance to you, as a Machinist's Mate, are discussed in the paragraphs which follow.

Deaerating Feed Tank Water Level Drops During Steady Steaming

SYMPTOM indicated by drop in water-level gage.

CAUSES:

1. Excessive use of feed-water.
2. Damage or malfunction of tank or machinery components.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Examine condensate pump for proper operation, make corrective adjustments if practicable.
3. Examine manually-operated recirculating valves, close them if found to be open. In ships equipped with by-pass regulating valve around air ejectors, examine and adjust this valve for proper operation.
4. Check water level in main condenser. Start-up standby condensate pump should water level be too high.

CAUTION: This should be accomplished gradually, paying close attention to the exhaust pressure.

5. Check with other engine rooms for make-up or excess feed water conditions. If these are found to be satisfactory, take on make-up feed.

NOTE: In some ships make-up feed is taken automatically, and a by-pass is provided in case the automatic feature malfunctions.

Deaerating Feed Tank
Too Full

SYMPTOMS:

1. Water-level gage too high.
2. Feed water pressure above normal.

CAUSES:

1. Incorrect alignment or cross-connecting of feed water tanks.
2. Malfunction of associated pumps.

ACTION TO BE TAKEN:

1. Notify Main Engine Control, and keep them informed.
2. Examine feed-booster pump operation, adjust if practicable.
3. Examine make-up feed valve, and make certain that it is in full closed condition.
4. If other engine room can take some feed, open condensate cross-over valves and close-off condensate to deaerating feed tank; or open excess feed valve deaerating feed tank to feed bottom. This is automatic in some ships and is provided with a by-pass.

Casualty to
Deaerating Feed Tank (DFT)

SYMPTOMS:

1. Sputtering or extinguishment of fires.
2. Boiler feed-water pressure gage fluctuates excessively.
3. Feed pumps race or slow down, operate irregularly and with excessive noise.

CAUSES:

1. Structural damage to tank and feed-water system.
2. Malfunction of pumps and piping supply feed-water to tank.
3. Excessive use of feed water.

ACTION TO BE TAKEN:

1. Notify Main Engine Control, and keep them informed.
2. When steaming split-plant with all deaerating feed tanks in use:

a. Start stand-by main feed and booster pumps in the opposite engine room.
b. Secure main feed and booster pumps in the deaerating feed tank, in engine room having the casualty.
c. Secure exhaust steam to the DFT, and route it to the opposite deaerating feed tank.
d. Secure high-pressure drains, and route them to the opposite deaerating feed tank.
e. Secure fuel-heater drains, and route them to the opposite deaerating feed tank.
f. Secure condensate discharge to the deaerating feed tank and discharge it into the opposite deaerating feed tank.
g. Open vent on the deaerating feed tank, in use for feed, and shift make-up feed to that engine room.

COOLING WATER
TO AUXILIARIES FAILS

The symptom is the casualty.

CAUSES:

Damage to, or malfunction of cooling water system.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Take cooling water from firemain. Start pump(s) as necessary.
3. Cross-connect independent cooling-water system, if installed.
4. Use portable pumps for cooling, should other means fail or not be practicable.

NOTE: The use of portable gasoline driven pumps in engine rooms requires exhaust fumes to be vented properly.

EXCESSIVE VIBRATION AND UNUSUAL NOISES

Engineroom casualties concerning excessive vibration and unusual noises are discussed in the section which follow.

Shaft Vibrates Excessively

Symptoms are the casualty.

CAUSES:

1. Malfunction or damaged driving unit.
2. Malfunction or damage in the bearings and shafting system.
3. Unbalanced or damaged propeller.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Slow engine (turbine). Speed up other engine (turbine) to maintain speed.
3. If vibration continues, Main Engine Control shall order all engines (turbines) to be slowed until cause has been determined.
4. Main Engine Control shall:
   a. Notify bridge of casualty, action being taken, and estimated time to make repairs.
   b. Request permission to reduce speed if necessary.
5. Make thorough inspection of affected engine, associated machinery, shaft bearings and spring bearings.
6. When practicable, inspect propeller, fairwaters, and rope guards.
7. If vibration continues, and is excessive at required speeds, stop the engine (turbine) and lock the shaft.
8. Check for vibration from the driving unit, shafting system and propeller prior to inspection gearing for source of vibration.

Turbine Vibration

The symptom is the vibration of the turbine.

CAUSES:

1. Loose foundation hold-down bolts on turbine and reduction gear.
2. A rumbling noise probably indicates the presence of water in the casing.
   a. Excessive boiler priming.
   b. Inadequate casing drainage.
3. Turbine standing idle for more than 5 minutes (in some plants) without being spun, could bow the rotor temporarily.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Slow engine (turbine) and reduce superheat temperature.
3. A brief slowing of the turbine will permit bowed rotor to straighten.
4. Inspect and clear casing drains.
5. Main Engine Control must:
   a. Notify bridge of casualty, action being taken, and estimate the time required to correct the situation.
   b. Request permission to adjust speed as necessary.
   c. Direct fireroom to check, and adjust if necessary, excessive boiler priming.
6. Inspect and secure foundation hold-down bolts on turbines and reduction gear.

Unusual Noise in Reduction Gear

The symptom (noise) indicates the development of, or occurrence of a casualty.

CAUSES:

1. Failure of lubrication system.
2. Babbitt metal or other foreign matter in lubrication oil system.

3. Loose fittings and/or cover plates.
4. Changing speeds with shafts operating in different directions.
5. Ship operating in shallow water.
6. Loosening of hold-down bolts on main turbine and reduction gear.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Slow engine immediately, and stop engine if the noise persists.
3. Main Engine Control must:
a. Notify bridge of casualty, action being taken, and estimated time required to make corrections.
b. Request permission to adjust speed as necessary.
4. Check lubrication oil discharge pressure, temperature of the bearings, operation of oil sprays, and strainers for the presence of babbitt metal or foreign matter.
5. Check and secure loose fittings and cover plates which could cause the noise.
6. Check and secure hold-down bolts on main turbine and reduction gear.
7. If the noise is very loud or has a roaring characteristic:

a. Check shaft and spring bearings.
b. Lock shaft and make such investigations as the operation of the ship will permit.
c. The opening of the gear case will not be done until all other possible sources have been investigated.

Metallic Noise
Emanating from Turbine

The sympton is the casualty.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Stop engine.
3. Lock the shaft and do not operate until the cause has been determined.
4. Main Engine Control must:

a. Notify bridge of casualty, action being taken, and estimate of time required to make repairs.
b. Request permission to adjust speed as necessary.

HOT BEARINGS

Turbine Bearings

SYMPTOM: Bearing temperatures rise above the maximum allowed.

CAUSES:

1. Malfunction of lubrication system; valves, piping or other components clogged or ruptured.
2. Babbitt metal or foreign matter in lubrication oil strainers.
3. Insufficient oil discharge from the cooler.
4. Inadequate supply and/or improper quality of lubrication oil.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Verify proper quantity and temperature of oil from design of cooler and provide an adequate supply to the bearings. Readjust individual bearing needle-valves to increase flow.
3. Slow the engine if necessary to maintain bearing temperature within the manufacturer's limit, or as experience dictates.
4. Inspect lube oil strainers for presence of babbitt metal, or foreign matter.
5. Until a remedy is applied, the turbine must be slowed as necessary to avoid exceeding the safe bearing temperature. The turbine will be stopped only to prevent damage. Maintain low-speed operation so that bearing temperatures will be lowered to safe limits before stopping, so as to prevent bearing(s) from seizing. If, after slowing to minimum operating speed (or under actual combat conditions), bearing temperature(s) continue to rise (with known good oil supply) apply emergency sea water cooling to the external housing, from the firemain or other readily available source.
6. Main Engine Control must:

a. Notify bridge of casualty action being taken, and an estimate of time required to correct the situation.
b. Request permission to adjust speed as necessary.

Reduction Gear Bearings

SYMPTOM: Bearing temperature rises above maximum allowed.

CAUSES:

1. Pinion or shaft misalignment.
2. Uneven gear wear.
3. Malfunction of lubricating oil system; valves, piping or other components clogged or ruptured.
4. Insufficient lubrication oil supply.
5. Improper quality of, or contamination (water) of lubricating oil.

ACTION TO BE TAKEN:

1. Notify Main Engine Control, and keep them informed.
2. Except in an emergency, do not operate the gear until the bearings have been examined.
3. Slow shaft when necessary to maintain safe bearing temperature.
4. Increase the flow of circulating water to the lubrication oil coolers.
5. Stop and lock shaft immediately if bearing temperature exceeds maximum allowable (185°F).
6. Main Engine Control must:
 a. Notify bridge of casualty, action being taken, and estimate of time required to correct the condition.
 b. Request permission to adjust speed as necessary.

Line Shaft Bearings

SYMPTOM: Bearing temperature rises above maximum allowed.

CAUSES:

1. Insufficient quantity of lubricating oil.
2. Quality of or contamination of lubrication oil being fed to bearing.
3. Malfunction of valves, piping or components of lubricating oil system.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Reduce shaft speed so as not to require the wiping of the shaft bearing.
3. Verify quantity and quality of lubrication oil being supplied to bearing.
4. Increase the flow of circulating water to the lubrication oil coolers.
5. Employ artificial cooling if practicable. Portable blowers or water from the fire main may also be used. Prevent water from contaminating the lubrication oil supply.
6. Inspect slinger rings, foundation hold-down bolts.
7. Where practicable, inspect lubrication oil reservoir for metal particles or foreign matter.
8. Main Engine Control must:
 a. Notify bridge of casualty, action being taken, and give an estimate of time required to correct condition.
 b. Request permission to adjust speed as required.

TREATMENT OF OVERHEATED TURBINE, REDUCTION GEAR, AND LINE SHAFT BEARINGS

The following steps should be followed when turbine, reduction gear, or line shaft bearings become overheated:

1. After the bearing temperature has been reduced from the critical temperature range, by the use of water, blowers, or other methods, proceed at a speed which will maintain the bearing temperature within the satisfactory range.
2. When the bearing temperature has not dropped enough, and might damage the turbine shaft-packing, allowing the shaft to whip or transfer an excessive load to adjacent shaft bearings, proceed at moderate speed until the shaft can be stopped and the affected bearing replaced.
3. Where bearing damage is considered to be greater than that described in 2 above, turn over the shaft at minimum speed to prevent the bearing from FREEZING. When the bearing has been cooled below the critical range, stop the engine and lock the shaft. Continue operation of the pressure lubrication oil system.
4. Renew or renovate lubrication oil prior to returning engine to service.
5. Main Engine Control must:
 a. Notify bridge of procedure required.
 b. Request permission to adjust speed as necessary.

JAMMED THROTTLE (AHEAD AND ASTERN)

Action to be taken when ahead throttle valve jams open:

1. Close guarding valve or main line stop valve. Guarding valve may be used for limited throttling as necessary.

2. Use astern throttle to stop shaft in extreme emergency.

Action to be taken when astern throttle valve jams open:

1. Close line stop valve.
2. Use ahead throttle to stop shaft in extreme emergency.

NOTE: On some modern combatant ships, the guarding valve controls the steam to both the ahead and astern throttles. In such cases, should either throttle jam, the casualty is controlled by closing the guarding valve. The shaft CANNOT be stopped by using the opposite throttle.

GAGE GLASS ON EVAPORATOR BREAKS

The symptom is the casualty.

CAUSES:

1. Excessive shock and/or vibration.
2. Physical impact by foreign object.

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Secure valves at top and bottom of gage glass, and install a new gage glass.
3. Control water level by looking through the glass port on side of evaporator shell.
4. If valves on gage glass leak and vacuum is lost, secure the evaporators and install another gage glass.

FIREROOM CASUALTIES

As an MM3 or MM2, you will be concerned with various fireroom casualties. In general, the Boiler Technician is responsible for taking the necessary steps to control fireroom casualties. However, it will become necessary for the Machinist's Mate to carry out proper procedures to control the casualties which have a direct effect on the operation of the engineroom. Close cooperation between the engineroom and fireroom personnel is necessary for the most efficient handling of engineering casualties.

Under all circumstances, the Boiler Technician will notify the engineroom of the fireroom casualties. The necessary action that must be taken will be based on the report given by the Boiler Technician. When a fireroom casualty affects the operation of the engineroom, cooperation and communication between personnel of both the spaces are extremely important. Lack of (or improper) communication or cooperation can be the indirect cause of a casualty getting out of control and resulting in serious damage to machinery and injury to personnel. Main engine control must receive all important information in order to coordinate the handling of the casualty. Main engine control must have all vital information to keep the officer of the deck informed as to the status of the machinery and the maximum speed the ship can make.

Some of the fireroom casualties that affect the engineroom, and the procedures for controlling them, are listed in the following paragraphs.

If the fireroom informs the engineroom that the salinity of the boilers is excessively high and that the boilers may be receiving feed water which has a high salinity content, the Machinist's Mate should check all sources of feed water contamination that are his responsibility and proceed as follows:

HIGH SALINITY IN STEAMING BOILER

SYMPTOMS:

1. Test of boiler feed water indicates that the chloride content is above limits.
2. Priming and/or carry-over in the boiler.

CAUSES:

1. Failure of the evaporators to function properly.
2. Failure in one boiler causing carry-over to another boiler.

ACTION TO BE TAKEN BY FIREROOM:

1. Notify Main Engine Control and keep them informed.
2. Request permission of MEC to blow down the boiler.
3. Blow the boiler through mud-drum. Do not allow the water level to fall below the safe level in the steam drum. Continue successive short blow-downs until the desired salinity has been reached, or the quantity of make-up feed available for blowing down has been expended. Check chloride content after each blow-down.

4. Add disodium phosphate and caustic soda to maintain pH and phosphate within proper limits.

5. Should the high saline feed water continue to be fed to the boiler (due to condenser failure), it will be necessary to reduce the firing rate to prevent carry-over.

6. Do not blow-down the water wall headers while fires are lighted. Reduction of boiler water salinity can be made by surface blowing the boiler.

ACTION TO BE TAKEN BY ENGINEROOM:

1. When directed by Main Engine Control, reduce speed as necessary to prevent priming.
2. Check condensate for salt content and take remedial action as specified.

ACTION TO BE TAKEN BY MAIN ENGINE CONTROL:

1. Notify bridge of casualty, action being taken, and an estimate of the time required to make corrections.
2. Request permission to adjust speed as necessary.

POSSIBLE ADDITIONAL CASUALTIES:

1. Rapid clogging (scaling) of boiler tubes.
2. Loss of boiler until retubing has been accomplished.

FORCED DRAFT BLOWER FAILURE

SYMPTOMS:

1. Blower stops, or races without moving air.
2. Excessive smoke in the stack gases.

CAUSES:

1. Mechanical failure of pump.
2. Electric power failure.

ACTION TO BE TAKEN BY FIREROOM:

1. Notify Main Engine Control and keep them informed.
2. Place boiler master (if only one blower on line) and damage blower selector stations in remote manual. (ACC System). Reduce loading pressure to minimum.
3. If two forced air blowers are in use, increase speed of operating blower.
4. With only one blower in use, secure burners at once to prevent flareback.
5. Start standby blower and relight fires.

ACTION TO BE TAKEN BY ENGINEROOM:

1. Close throttle as necessary to maintain steam pressure.
2. Should steam pressure drop below the minimum allowable, order the boiler to be secured and the plant cross-connected.

ACTION TO BE TAKEN BY MAIN ENGINE CONTROL:

1. Notify bridge of casualty, action being taken, and estimated time required to make repairs.
2. Request reduction of speed if required.

POSSIBLE ADDITIONAL CASUALTIES:

1. Loss of auxiliary steam and steam-driven auxiliaries.
2. Loss of electric power and electric-driven auxiliaries.
3. Low or loss of lube oil pressure.
4. Loss of booster pressure.
5. Loss of feed pressure.
6. Loss of vacuum.
7. Loss of auxiliary exhaust.

LOSS OF FUEL SUCTION

SYMPTOMS:

1. Momentary excessive sputtering of atomizers.
2. Fuel oil pressure drop rapidly.
3. Fires are extinguished.
4. Fuel oil service pump races.
5. Fuel oil service pump is noisy.

CAUSES:

1. Empty fuel oil service tank.
2. Clogged or ruptured pump suction line.
3. Fuel oil service pump failure.

ACTION TO BE TAKEN:

1. Notify Main Engine Control.
2. Secure all burners. Leave one register open on the saturated and superheater side to

expel gases and to aid in combustion of accumulated oil on the furnace deck.

3. Keep force-draft blower running to maintain approximately 2-inches air pressure in the boiler casing.

4. Open auxiliary, turbo-generator and main steam cross-connection valves when directed by Main Engine Control.

5. Shift oil suction to stand-by tank and start stand-by service pump.

6. Secure boiler if steam pressure drops to 85 percent of the working pressure.

7. When oil is available, light fires and investigate cause of the casualty.

8. Upon notification of loss of fuel oil pressure, Main Engine Control should:

a. Notify the bridge and order the affected engineroom to close throttles to conserve steam, if this action is operationally feasible.

b. Order all stations to standby to cross-connect.

c. When affected boiler is secured, order plant cross-connected.

d. Notify bridge of speed restrictions, nature of casualty, and estimated time of repair.

POSSIBLE SECONDARY CASUALTIES—In the above procedures, the original casualty was isolated when the boiler stops were closed. Secondary casualties could have extended to all areas where steam or electric auxiliaries were in use, and whose power was supplied by the secured boiler. The number of secondary casualties could be determined by the thoroughness and speed with which the operating personnel handled the shift over to an alternate source at their stations. Progressive casualties are a frequent occurrence.

POSSIBLE ADDITIONAL CASUALTIES:

1. Loss of auxiliary steam pressure and steam-driven auxiliaries.
2. Loss of electric power and electric-driven auxiliaries.
3. Low or loss of lube oil pressure (a serious casualty).
4. Loss of booster pressure.
5. Loss of feed pressure.
6. Loss of vacuum.
7. Loss of auxiliary exhaust.

Any fireroom casualty affecting the engineroom or engineroom casualty affecting the fireroom requires complete cooperation between the personnel of all spaces concerned, plus close coordination of the corrective procedures by the officer of the watch. A minor casualty can quickly become a major casualty if improper procedures are used. Thorough training of all engineering department watchstanders can be the difference between effective and ineffective action taken to control casualties. All personnel, not just a few KEY men, should know the engineering plant—each piece of machinery, the piping systems, how each unit is used in conjunction with other units, and how each casualty affects the operation of another space or other spaces.

BATTLE DAMAGE CASUALTIES

As an MM3 or MM2, you will also be responsible for knowing how to handle battle casualties. Speed is a critical factor when applying corrective procedures to battle casualties. But speed is not the only factor to be considered, CORRECT ACTION must be taken. Thorough training of all personnel concerned is essential in applying proper procedures in handling battle casualties.

This section contains information on some of the different types of battle casualties. You must be familiar with the procedures as presented both in this section and in other publications that cover them in greater detail. Naval Ships Technical Manual, your own ship's Damage Control Book, Engineering Casualty Control Manual, and Ship Repair Party Manual are publications which contain very important information which you must know.

RUPTURE IN FIREMAIN PIPING

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.

2. When the firemain is ruptured on the discharge side of the firemain pump:

a. Secure cutout valves at the point where the pump discharge line connects to the firemain.

b. Secure pump discharge valves.

c. Secure cutoff valves at either side of the firemain rupture.

d. Slow or stop fire pump as required.

(1) Fire hose jumpers can be rigged between fire plugs located on pressure side of cut-off valves at both sides of the piping rupture.

(2) Rig portable, gasoline driven pump to discharge flooding water over the side, through discharge fittings in upper hull.

(3) When portable, gasoline driven pumps are used, a provision must be made to vent off engine exhaust fumes.

RUPTURE IN MAIN FEED PIPING

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Stop main feed pump.
3. Start emergency feed pump and feed through auxiliary feed system, if fitted, and close main feed stop and check valve.
4. If danger of low water exists, secure boiler.
5. Isolate section of damaged piping and restore main feed service if practicable, using main or emergency feed pump as appropriate.

RUPTURE IN HIGH PRESSURE DRAIN PIPING

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Close bulkhead stop(s) and isolate damaged section of high-pressure drain system.
3. If escaping vapor hinders operation, close traps and crack funnel and bilge drains.

NOTE: To conserve feed water, crack drains in piping system only at points where condensate is likely to accumulate.

4. If rupture is at deaerating feed tank, close high-pressure drain valves at entrance to the deaerating feed tank.

NOTE: When the high-pressure drainage system cannot be used, drain units to the funnel drain system as frequently as required.

RUPTURE IN FUEL OIL HEATING DRAIN PIPING

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Isolate damaged section by securing bulkhead stops.
3. Allow drainage from isolated section to flow into the bilge.
4. Plug drain piping.
5. Repair or replace damaged or ruptured piping.

RUPTURE IN SALT WATER COOLING SERVICE PIPING

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Secure cut-off valves nearest to both sides of the rupture.
3. Plug or repair damaged piping.
4. Rig hose jumpers across or cross-connect around ruptured piping section, to provide cooling water to machinery components which require this cooling feature.

RUPTURE IN FUEL OIL SUCTION AND TRANSFER PIPING

ACTION TO BE TAKEN:

1. Notify Main Engine Control and keep them informed.
2. Stop transfer pump.
3. Isolate damaged section, and use transfer line on opposite side.
4. Repair or replace damaged section.

STEERING GEAR AND PROPELLER CASUALTY—NEAR MISS

ACTION TO BE TAKEN:

1. Notify Main Engine Control of casualty and keep them informed.
2. Stop engine(s) and lock shaft if damaged rudder is fouling propeller(s), and if situation permits. (Take action on orders from Main Engine Control.)

ELECTRICAL CASUALTY CONTROL

In designing a naval ship's electric plant, every effort has been made to obtain the greatest reliability and continuity of service under casualty conditions. Full understanding of these design features can best be attained by training and the practice in the proper use of the equipment and systems provided. Programs of education,

training and maintenance are of vital importance for effective damage control.

Damage control books contain diagrams of the various systems, and other valuable information for electrical casualty control. "Battle Control Instructions" (NWIP 50 Series) require that an Engineering Casualty Control Book be prepared for use in the engineering department and the type of information that it shall contain is specified.

In any casualty involving damage to electrical cable and equipment, the electrical circuits of which they may be a part, may be a hazard if they remain energized. The circumstances surrounding each case of damage will dictate the action to be taken. In case of serious damage, it is usually necessary to remove electrical power from all cables in the damaged area, to prevent the ignition of combustible liquids and gases. Operational circumstances, however, may require reestablishment of power to undamaged circuits, particularly those which extend through the damaged area. The time and labor which will be required to accomplish these actions, will depend on the familiarity with, and the ready availability of information regarding the ship's electric plant.

All personnel must be familiar with the purpose and use of electrical damage control equipment. This is particularly true with respect to the casualty power system, as the maintenance of watertight integrity may require personnel, other than the electrical department, to make cable connections. In casualty power drills, interruption to normal power, and re-energizing equipment by means of the casualty power system, is desirable.

Some equipment could be damaged by power interruption. In these cases, the equipment must be:

1. Carefully de-energized prior to the casualty power drill.
2. The equipment supplied with a source of power not involved in the drill or,
3. The interruption be limited to portions of the power system not involving the susceptible equipment, or
4. The drill be only simulated.

THE ELECTRIC PLANT

Electric power is used in naval ships to operate numerous services which are indispensable to its fighting effectiveness. Electric power trains and elevates the guns and missile launchers, moves the rudder, runs important auxiliaries, supplies light, and operates interior communication, as well as radio, radar, and sonar systems. A ship without electric power has little value as a fighting unit.

The ship's power and lighting electrical systems have been designed to provide a high degree of flexibility to ensure continuity of essential power and lighting services under normal and casualty conditions. Basically the ship's power and lighting electrical systems consist of the three principal elements: (1) the ship service system, (2) the emergency system, and (3) the casualty power system. Each of these systems is designed with inherent damage control features to provide a continuous supply of power under casualty conditions. The general arrangement of the ship service electrical system is such that a faulty circuit will be removed automatically, through the selective operation of protective devices, without an appreciable interruption of power supply to other circuits. However, on failure of ship service generators, the emergency system is automatically placed in operation for battle services and, if both the ship service and emergency systems fail, temporary casualty power circuits can be rigged to supply power to vital auxiliaries. For example, in the event of a power failure on the normal ship service power supply feeder to the steering gear, the load will automatically be transferred to the emergency feeder. If power is not available from either source, power can be supplied temporarily by rigging the casualty power system. Thus, with these generator plant arrangements and the temporary casualty power arrangements, maximum reliability and flexibility are assured.

Electrical power is so essential to the military effectiveness of the ship, that maximum effort must be made to ensure continuity of service under casualty conditions. To provide an electric plant arrangement so that this fundamental requirement can be attained, the design arrangements include consideration of the relative locations of the ship service and emergency generator plants, wireways and bus ties, and the provision of a casualty power system. The ship service generator plant is divided into units, each unit consisting of one or two generators connected to an associated switchboard for their control, and a distribution system to carry the power to the ship service power and lighting systems. The plant design provides for a standby generator capacity in the event of loss of part of the generator plant. In general, the normal

feeders to the various loads will be taken from the nearest ship service generator plant. The emergency generator and switchboard are generally located as far forward and as far aft as practicable, separated from the nearest ship service generator and switchboard by at least two watertight transverse bulkheads. This is to minimize the possibility of damage to ship's service and emergency generators from the same cause. Each emergency generator has its own switchboard for the control of the generator and distribution of power.

Certain cables at switchboards, panels, transfer switches, and so forth, are sealed at their ends to prevent the flow of water and will also prevent the entrance of water into electrical equipment, thus avoiding the malfunctioning of intact electrical circuits.

EMERGENCY POWER SYSTEM

The emergency power system is provided to supply an immediate source of emergency power to vital ship functions requiring continuity of service for sustaining ship control, communication, detection, interior communication, and lighting.

It is designed to provide a source of emergency power for damage control functions, and limited operation of ordnance and aircraft facilities.

The emergency power system will provide power from the emergency switchboard, a normal source of ship service power through bus-tie feeders to selected electrical loads, thus utilizing the emergency switchboard as a ship service load center under normal conditions.

CASUALTY POWER SYSTEM

The casualty power distribution system is for making temporary connections if the permanently installed ship service and emergency distribution systems are damaged. It is not intended to supply circuits to all the electrical equipment in the ship BUT IS LIMITED TO THE FACILITIES NECESSARY TO KEEP AFLOAT AND GET IT OUT OF A DANGER AREA, as well as supply power to a limited number of ordnance items such as A.A. guns and their directors which may be necessary for the defense and protection of the ship.

Although the casualty power system is rigged and connected by the ship's electricians and other qualified personnel, the final authority to energize any casualty power circuit rests with the Damage Control Assistant, who, upon assuring himself that the system is ready in all respects to be energized, directs that such action be taken.

The casualty power for rigging temporary circuits is separate and distinct from the electrical damage control equipment. The latter consists of tools and appliances for cutting cables and making splices for temporary repair of the permanently installed ship service and emergency distribution systems.

Important features of the basic design of the casualty power supply system include the following:

1. Preservation of the watertight integrity of the ship.
2. Simplicity of installation and operation.
3. Flexibility of application.
4. Interchangeability of parts and equipment.
5. Minimum of weight and space requirements.
6. Ability to accomplish desired functions.
7. The casualty power system is an emergency method of providing power and is not a method of making temporary repairs.

The casualty power system is purposely limited in its scope so as to retain its effectiveness. The more equipment added and the more the system is expanded, the greater is the possibility of error in making connections, with the possibility that failure in relatively unimportant equipment will cause loss of power needed for vital equipment. It is also probable that, should the casualty power system be so expanded, it would be so burdened with miscellaneous loads that its ability to supply the required power load for vital needs would be dangerously reduced.

EMERGENCY FIRE PUMPS

Most ships have electric-driven fire pumps located outside the engineering spaces. These pumps furnish water under pressure to their own piping system or to the ship's firemain. Provisions are made for different sources of electrical power to these pumps: Normal and alternate supply from the ship's service generators, emergency supply from the diesel-driven emergency generators, and the casualty power system.

Many ships, such as carriers, tankers, and tugs, have independent diesel-driven fire pumps.

In case of damage to the ship's pumps and firemain, these diesel-driven pumps can furnish large amounts of water for firefighting purposes. Many of the tugs have diesel-driven pumps and other facilities installed for fighting fire on other ships, piers, and docks.

LIGHTING SYSTEM

On ships using a-c generators, the ship's service and emergency lighting systems are energized from the generator and distribution switchboards through a bank of transformers. These transformers supply power to the lighting system through the lighting distribution panels.

Lighting throughout the machinery spaces is supplied from the normal switchboard for the compartments involved, with some lights in each space supplied from the alternate switchboard. A few lights in each compartment are supplied through automatic bus transfer equipment from circuits originating at the emergency switchboards.

In the event of complete failure of the ship's service and emergency lighting systems, automatic type hand lanterns are provided to supply an instantaneous source of illumination. These relay-operated hand lanterns are installed at vital stations. In addition, non-automatic type hand lanterns are installed at strategic locations. Although the Electrician's Mates have the responsibility for the maintenance of the hand battle lanterns, it is the duty of the petty officer in charge of the space to see that his men do not remove the lanterns or use them for unauthorized purposes. If the Electrician's Mates do not properly maintain the battle lanterns, the petty officer in charge should report the fact to the appropriate Electrician's Mate or take any other action that may be necessary.

RADIOLOGICAL MONITORING

Radiological monitoring teams, aboard ship, are made up of personnel from the damage control parties and the medical department. You, as an MM, will be required to use radiac instruments and perform monitoring operations on salt water intake lines and engineering ventilation systems.

The instruments used for surveying radiological contamination are known as RADIACS. Various types of radiacs are used aboard ship, since no single type of radiac can make all the measurements that may be required. The radiacs that you may use aboard ship include (1) survey meters for measuring gamma radiation, (2) survey meters for measuring gamma and beta radiation, (3) survey meters for measuring alpha radiation, and (4) dosimeters for measuring accumulated doses of radiation received by individuals.

The radiac instruments and methods of radiation detection are discussed in Military Requirements for Petty Officer 3 & 2, NAVPERS 10056-C.

The purpose of a radiological monitoring survey is to determine the location, type, and intensity of radiological contamination. The type of monitoring survey made at any time depends on the radiological situation and on the tactical situation. GROSS or RAPID SURVEYS are made soon as possible after a nuclear weapon has been exploded, to get a general idea of the extent of contamination. DETAILLED SURVEYS, made later, give a more complete picture of the radiological situation.

On board ship, two main types of radiological surveys would be required after a nuclear attack. SHIP SURVEYS (first gross, then detailed) include surveys of all weather decks, interior spaces, machinery spaces, circulating water and air systems. An MM monitoring in a machinery space would be primarily concerned with surveying contamination in systems using sea water; main and auxiliary condensers, distilling plants, fire pumps and cooling water pumps. Later and more detailed surveys are made by personnel from damage control parties. The medical department makes clinical tests, maintains dosage records, and makes specific recommendations concerning monitoring of food, water, and air.

Detailed instructions for making monitoring surveys cannot be specified for all situations, since a great many factors must be considered before monitoring procedures can be decided on. Monitors must be thoroughly trained before the need for monitoring arises. Simulated practice will teach something about the general movements made by a monitor, but it will not prepare him to actually use the radiac instruments. All personnel who may be required to perform monitoring operations should be given instructions and practice in the use of all types of radiacs available on board ship.

CHAPTER 18

LATHES AND LATHE MACHINING OPERATIONS

Although machine shop work is generally done by men in other ratings, there may be times when you will find the lathe essential to complete a repair job, and you are required to know the purpose and principles of operation of lathes. There are a number of different types of lathes installed in the machine shops of various Navy ships, including the engine lathe, horizontal turret lathe, vertical turret lathe, and several variations of the basic engine lathe, such as bench, toolroom, and gap lathes. All lathes, except the vertical turret type, have one thing in common in that for all usual machining operations the workpiece is held and rotated about a horizontal axis, while being formed to size and shape by a cutting tool. In the vertical turret lathe, the workpiece is rotated about a vertical axis. Of the various types of lathes, the type you are most likely to use is the engine lathe; therefore, this chapter deals only with lathes of that type and the machining operations you may be required to perform.

THE ENGINE LATHE

An engine lathe similar to the one shown in figure 18-1 is found in every machine shop, however small. It is used principally for turning, boring, facing, and screw cutting, but it may also be used for drilling, reaming, knurling, grinding, spinning, and spring winding. The work held in the engine lathe can be revolved at any one of a number of different speeds, and the cutting tool can be accurately controlled by hand or power for longitudinal feed and crossfeed. (Longitudinal feed is the movement of the cutting tool parallel to the axis of the lathe; crossfeed is the movement of the cutting tool perpendicular to the axis of the lathe.)

Lathe size is determined by two measurements: (1) the diameter of work it will swing over the bed or the diameter of work it will swing over the cross-slide, and (2) the length of the bed, or the maximum distance between centers. For example, a 14-inch x 6-foot lathe will swing work (over the bed) up to 14 inches in diameter, and has a bed that is 6 feet long.

Engine lathes are built in various sizes ranging from small bench lathes having a swing of 9 inches to very large lathes for turning work of large diameter such as low pressure turbine rotors. The 16-inch lathe is the average size for general purposes, and is the size usually installed on ships having only one lathe.

PRINCIPAL PARTS

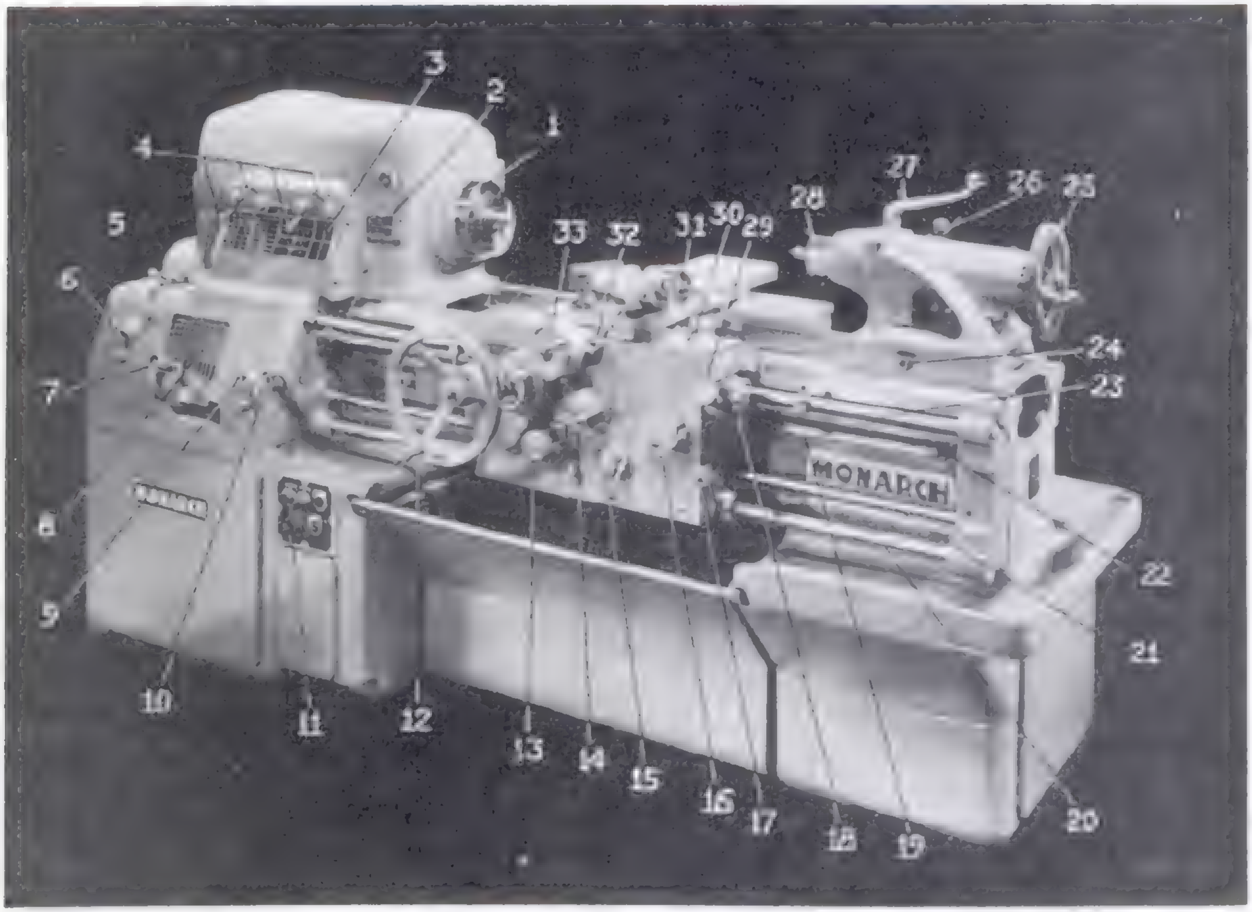
To learn the operation of a lathe, you must first become familiar with the names and functions of the principal parts. Lathes of differnet manufacture differ somewhat in details of construction, but all are built to perform the same general functions. As you read the description of each part, find its location on the lathe by referring to figure 18-1 and the figures which follow. (For specific details on the features of construction and operating techniques, refer to the manufacturer's technical manual for the machine you are using.)

Bed and Ways

The bed is the base or foundation of the working parts of the lathe. The main features of its construction are the ways which are formed on its upper surface and run the full length of the bed. They provide the means for maintaining the tailstock and carriage, which slide on them, in alignment with the headstock, which is permanently secured by bolts at one end (at operator's left).

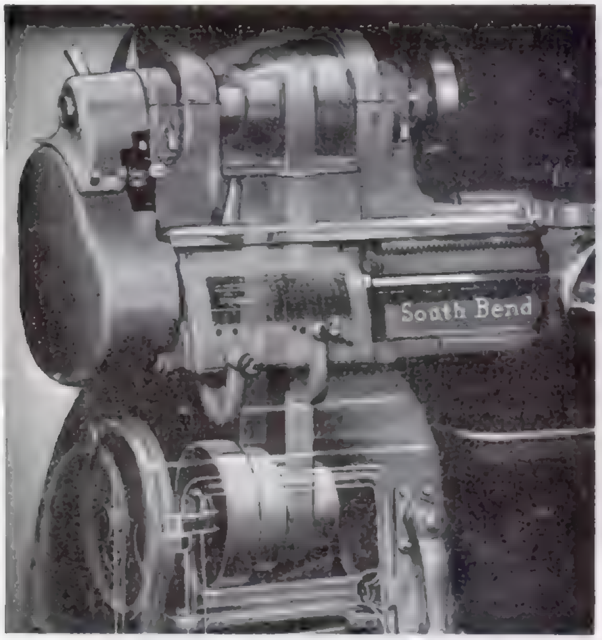
Headstock

The headstock carries the headstock spindle and the mechanism for driving it. In the belt-driven type, shown in figure 18-2, the driving mechanism consists merely of a cone pulley

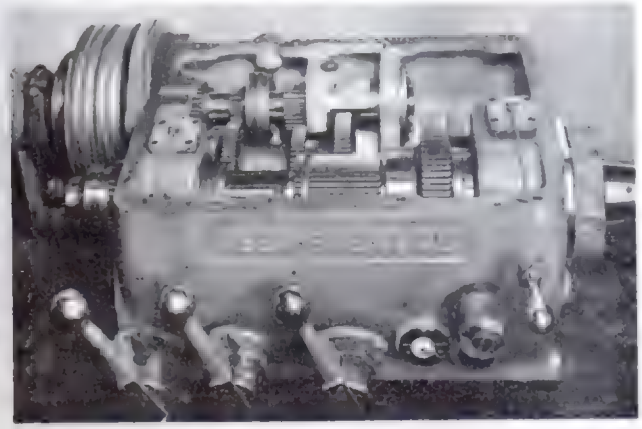


1. Headstock spindle
2. Identification plate
3. Spindle speed index plate
4. Headstock spindle speed change levers
5. Upper compound lever
6. Lower compound lever
7. Tumbler lever
8. Feed-thread index plate
9. Feed-thread lever
10. Spindle control lever
11. Electrical switch grouping
12. Apron handwheel
13. Longitudinal friction lever
14. Cross-feed friction lever
15. Feed directional control lever
16. Half nut closure lever
17. Spindle control lever
18. Leadscrew reverse lever
19. Reverse rod stop dog
20. Control rod
21. Feed rod
22. Lead screw
23. Reverse rod
24. Tailstock setover screw
25. Tailstock handwheel
26. Tailstock clamping lever
27. Tailstock spindle binder lever
28. Tailstock spindle
29. Chasing dial
30. Carriage binder clamp
31. Compound rest dial and handle
32. Thread chasing stop
33. Cross-feed dial and handle

28.69X
Figure 18-1.—An engine lathe.



28.71X
Figure 18-2.—Belt-driven type headstock.



28.72X
Figure 18-3.—Sliding gear type headstock.

that drives the spindle direct or through back gears. When driving direct, the spindle revolves with the cone pulley; when driving through the back gears, the spindle revolves more slowly than the cone pulley, which, in this case, turns freely on the spindle. Thus two speeds are obtainable with each position of the belt on the cone; if the cone pulley has four steps as illustrated, eight spindle speeds can be obtained.

The geared headstock shown in figure 18-3 is more complicated but more convenient to operate, because speed changes are accomplished by the mere shifting of gears. It is similar to an automobile transmission except that it has more gear-shift combinations and therefore a greater number of speed changes. A speed index plate attached to the headstock indicates the lever positions for obtaining the different spindle speeds.

Tailstock

The primary purpose of the tailstock is to hold the DEAD center to support one end of work being machined on centers. However, it can also be used to hold tapered shank drills, reamers, and drill chucks. It is movable on the ways along the length of the bed to accommodate work of varying lengths and can be clamped in the desired position by means of the tailstock clamping nut.

Before inserting a dead center, drill, or reamer, carefully clean the tapered shank and wipe out the tapered hole of the spindle. When holding drills or reamers in the tapered hole of a spindle, be sure they are tight enough so they will not revolve. If allowed to revolve, they will score the tapered hole and destroy its accuracy.

Carriage

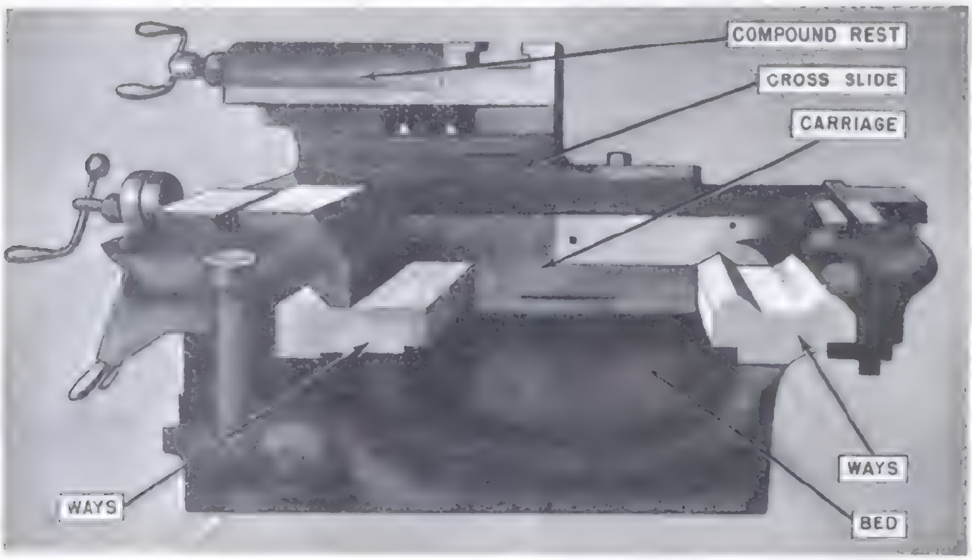
The function of the carriage is to carry the cross slide and the compound rest, which in turn carries the cutting tool in the tool post. Figure 18-4 shows how the carriage travels along the bed over which it slides on the outboard ways.

The carriage and cross slide are provided with T-slots or tapped holes for clamping work for boring or milling. When used in this manner the carriage and cross slide movement feeds the work to the cutting tool, which is revolved by the headstock spindle.

You can lock the carriage in any position on the bed by tightening up on the carriage binder clamp screw. This is done only when doing such work as facing or cutting-off, for which longitudinal feed is not required. Normally the carriage binder clamp should be kept in the released position. Always move the carriage by hand to be sure it is free before applying the automatic feed.

Apron

The apron is attached to the front of the carriage and contains the mechanism for con-



28.76X
Figure 18-4.—Side view of a carriage mounted on bed.

trolling the movement of the carriage for longitudinal feed and thread cutting, and the lateral movement of the cross-slide.

Feed Rod

The feed rod transmits power to the apron to drive the longitudinal feed and crossfeed mechanisms. The feed rod is driven by the spindle through a train of gears, and the ratio of its speed to that of the spindle can be varied by means of change gears to produce various rates of feed. The rotating feed rod drives gears in the apron, and these gears in turn drive the longitudinal feed and crossfeed mechanisms through friction clutches.

Lead Screw

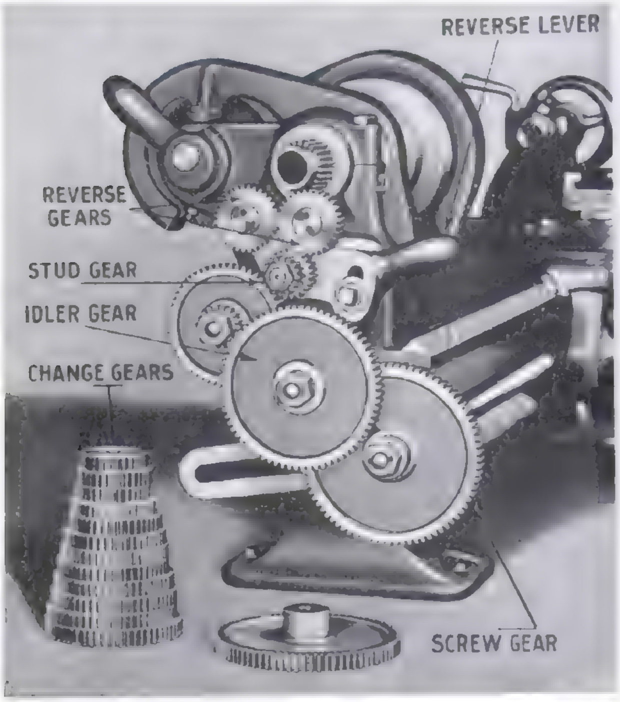
The lead screw is used for thread cutting. Along its length, it has accurately cut Acme threads, which engage the threads of the half-nuts in the apron when the half-nuts are clamped over it. When the lead screw turns in the closed half-nuts, the carriage moves along the ways a distance equal to the lead of the thread in each revolution of the lead screw. Since the lead screw is driven by the spindle through a gear train (fig. 18-5), the rotation of the lead screw bears a direct relation to the rotation of the spindle. Therefore, it may be seen that when the half-nuts are engaged, the longitudinal movement of the carriage is directly controlled by the spindle rotation, and consequently the cutting tool is moved a definite distance along the work for each revolution that it makes.

Compound Rest

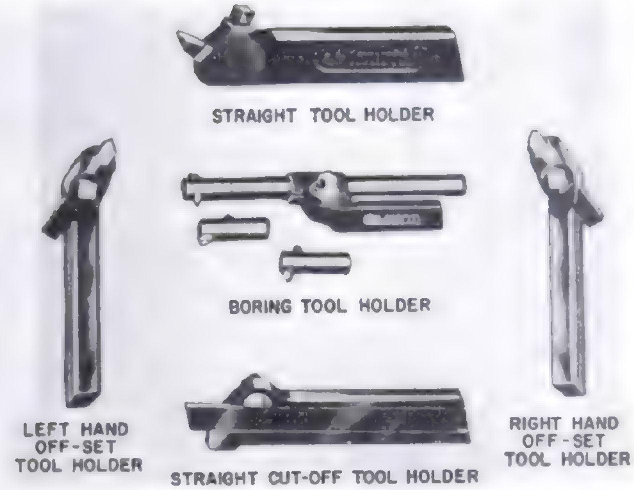
The compound rest provides a rigid adjustable mounting for the cutting tool. The compound rest assembly has the following principal parts:

1. The compound rest SWIVEL, which can be swung around to any desired angle and clamped in position. It is graduated over an arc of 90° on each side of its center position to facilitate setting to the angle selected. This feature is used when machining short, steep tapers such as the angle on bevel gears, valve disks, and lathe centers.
2. The compound rest TOP or TOP SLIDE, is mounted on the swivel section of a dovetailed slide. It is moved by means of the compound rest feed screw.

This arrangement permits feeding at any angle (determined by the angular setting of the swivel section), while the cross-slide feed provides only for feeding at right angles to the axis of the lathe. The graduated collars on the cross-feed and compound rest feed screws read in thousandths of an inch for fine adjustment in regulating the depth of cut.



28.80X
Figure 18-5.—Lead screw gear train.



28.67
Figure 18-6.—Common types of toolholders.

ATTACHMENTS AND ACCESSORIES

Accessories are the tools and equipment used in routine lathe machining operations. Attachments are special fixtures which may be secured to the lathe to extend the versatility of the lathe to include taper cutting, milling, and grinding. Some of the common accessories and attachments used on lathes are described in the following paragraphs.

Tool Post

The sole purpose of the tool post is to provide a rigid support for the tool. It is mounted in the T-slot of the compound rest top. A forged tool or a toolholder is inserted in the slot in the tool post. By tightening a screw, the whole unit is firmly clamped in place with the tool in the desired position.

Toolholders

Some of the common toolholders used in lathe work are illustrated in figure 18-6. Notice the angles at which the tool bits set in the various holders. These angles must be considered with respect to the angles ground in the tools and the angle that the toolholder is set with respect to the axis of the work.

Engine Lathe Tools

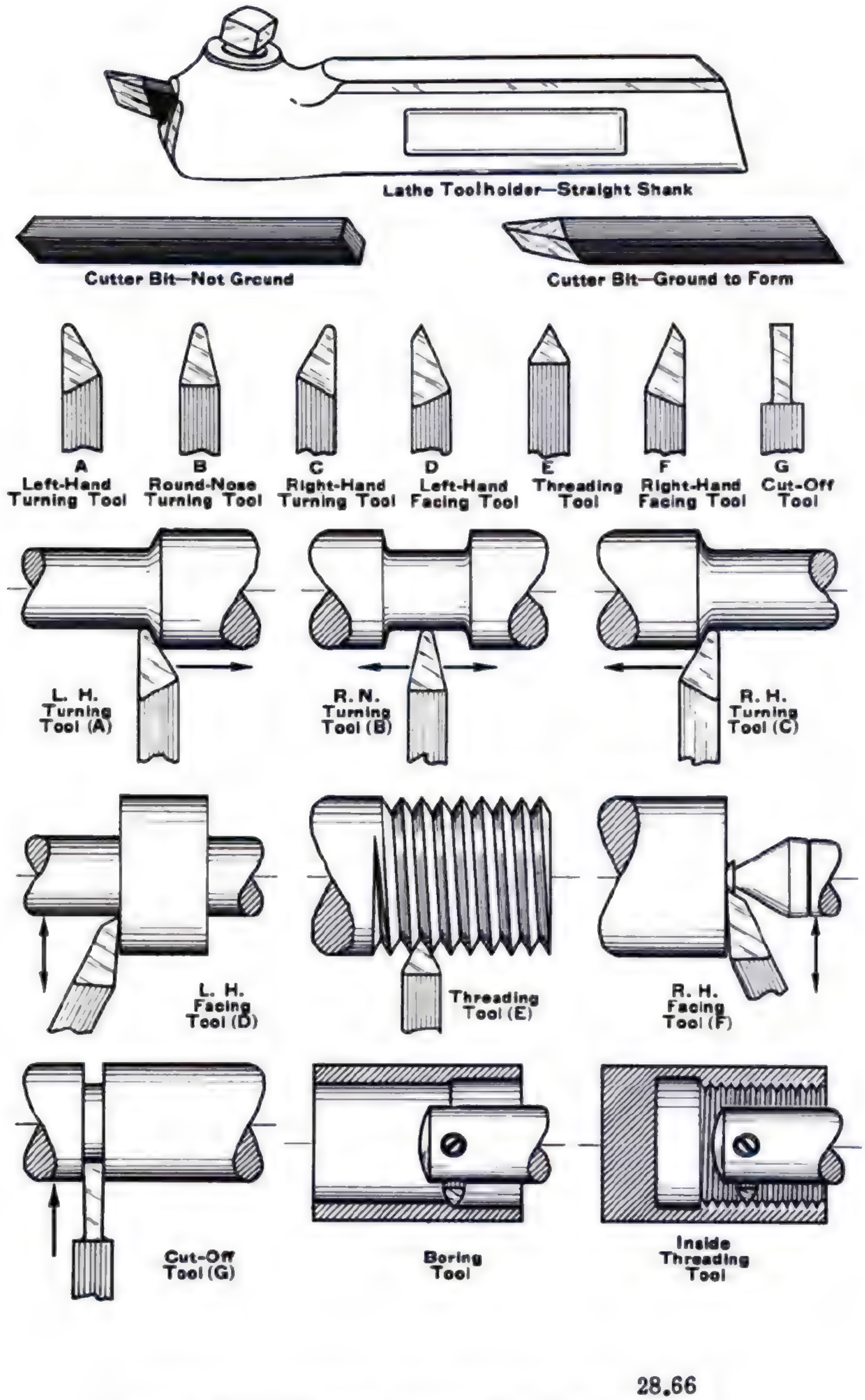
Figure 18-7 shows the most popular shapes of ground lathe tool cutter bits and their application. In the following paragraphs each of the types shown is described.

LEFT-HAND TURNING TOOL.—This tool is ground for machining work when fed from left to right, as indicated in A, figure 18-7. The cutting edge is on the right side of the tool and the top of the tool slopes down away from the cutting edge.

ROUND-NOSED TURNING TOOL.—This tool is for general all-round machine work and is used for taking light roughing cuts and finishing cuts. Usually, the top of the cutter bit is ground with side rake so that the tool may be fed from right to left. Sometimes this cutter bit is ground flat on top so that the tool mav ᵇe fed in either direction (B, fig. 18-7).

RIGHT-HAND TURNING TOOL.—This is just the opposite of the left-hand turning tool and is designed to cut when fed from right to left (C, fig. 18-7). The cutting edge is on the left side. This is an ideal tool for taking roughing cuts and for general all-round machine work.

LEFT-HAND FACING TOOL.—This tool is intended for facing on the left-hand side of the work, as shown in D, figure 18-7. The direction of feed is away from the lathe center. The cutting



28.66
Figure 18-7.—Lathe tools and their application.

edge is on the right-hand side of the tool and the point of the tool is sharp to permit machining a square corner.

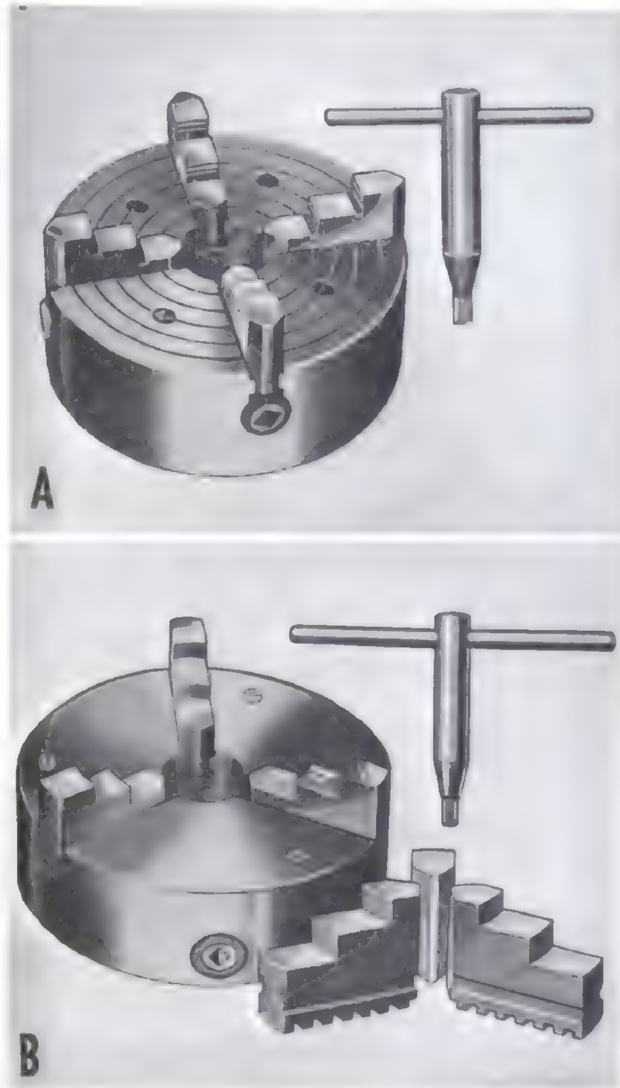
THREADING TOOL.—The point of the threading tool is ground to a 60° included angle for machining ANS screw threads (E, fig. 18-7). Usually the top of the tool is ground flat and there is clearance on both sides of the tool so that it will cut on both sides.

RIGHT-HAND FACING TOOL.—This tool is just the opposite of the left-hand facing tool and is intended for facing the right end of the work and for machining the right side of a shoulder. (See F, fig. 18-7.)

SQUARE-NOSED PARTING TOOL.—The principal cutting edge of this tool is on the front. (See G, fig. 18-7.) Both sides of the tool must have sufficient clearance to prevent binding and should be ground slightly narrower at the back than at the cutting edge. This tool is convenient for machining necks, grooves, squaring corners, and for cutting off.

BORING TOOL.—The boring tool is usually ground the same shape as the left-hand turning tool so that the cutting edge is on the front side of the cutter bit and may be fed in toward the headstock.

INTERNAL-THREADING TOOL.—The internal-threading tool is the same as the threading tool in E, figure 18-7, except that it is usually much smaller. Boring and internal-threading tools may require larger relief angles when used in small diameter holes.



28.90X
Figure 18-8.—Lathe chucks. A. Four-jaw independent chuck. B. Three-jaw universal chuck.

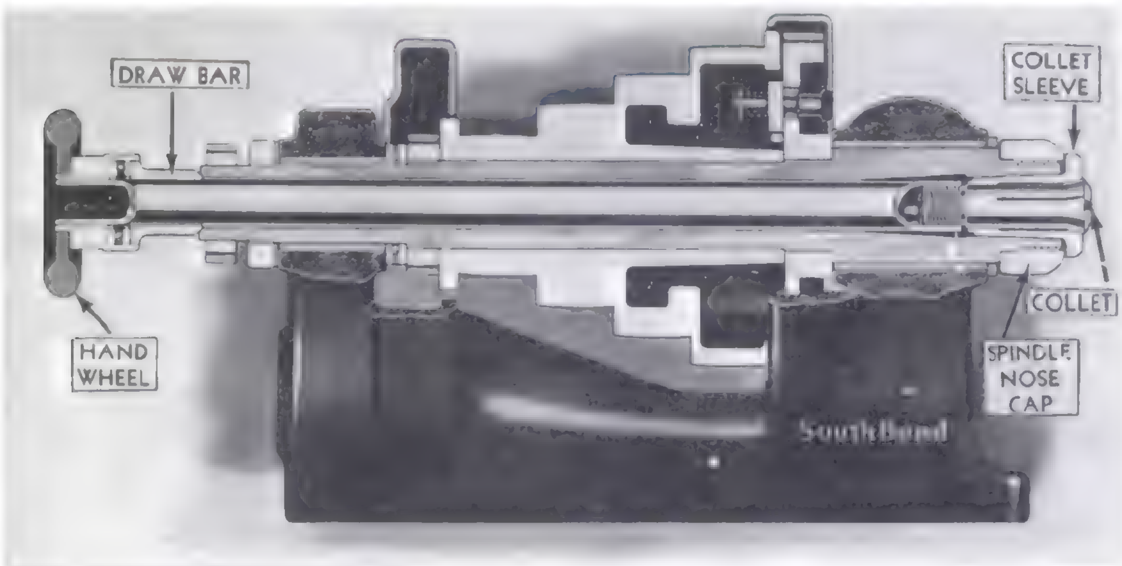
Lathe Chucks

The lathe chuck is a device for holding lathe work. It is mounted on the nose of the spindle. The work is held by jaws which can be moved in radial slots toward the center to clamp down on the sides of the work. These jaws are moved in and out by screws turned by a chuck wrench applied to the sockets located at the outer ends of the slots.

The 4-jaw independent lathe chuck, part A in figure 18-8, is the most practical for general work. The four jaws are adjusted one at a time, making it possible to hold work of various shapes and to adjust the center of the work to coincide with the center of the lathe. The jaws are reversible.

The 3-jaw universal or scroll chuck, part B in figure 18-8, can be used only for holding round or hexagonal work. All three jaws are moved in and out together in one operation. They move universally to bring the work on center automatically. This chuck is easier to operate than the 4-jaw type, but when its parts become worn, its accuracy in centering cannot be relied upon. Proper lubrication and constant care in use are necessary to ensure reliability.

The draw-in collet chuck is used to hold small work for machining in the lathe. It is the most



28.91X
Figure 18-9.—Draw-in collet chuck.

accurate type of chuck made and is intended for precision work.

Figure 18-9 shows the parts assembled in place in the lathe spindle.

The collet chuck which holds the work is a split-cylinder with an outside taper that fits into the tapered closing sleeve and screws into the threaded end of the hollow drawbar. Screwing up on the drawbar by turning the handwheel pulls the collet back into the tapered sleeve, thereby closing it firmly over the work, and centering it accurately and quickly. The size of the hole in the collet determines the diameter of the work it can accommodate.

Faceplates

You will use the faceplate for holding work of such shape and dimensions that it cannot be swung on centers or in a chuck. The T-slots and other openings on its surface provide convenient anchors for bolts and clamps used in securing the work to it. The faceplate is mounted on the nose of the spindle.

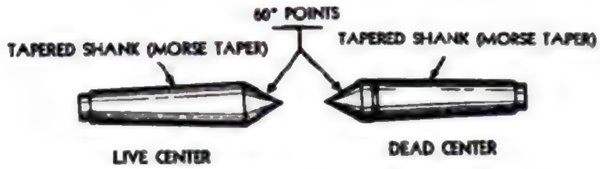
The driving plate is similar to a small faceplate and is used principally for driving work that is held between centers. The radial slot receives the bent tail of a lathe dog clamped to the work and thereby transmits rotary motion to the work.

Lathe Centers

The function of the 60° lathe centers shown in figure 18-10 is to provide a means for holding the work between points so it can be turned accurately on its axis. The head spindle center is called the LIVE center because it revolves with the work. The tailstock center is called the DEAD center because it does not turn. Both live and dead centers have shanks turned to a Morse taper to fit the tapered holes in the spindles; both have points finished to an angle of 60°. They differ only in that the dead center is hardened and tempered to resist the wearing effect of the work revolving on it. The live center revolves with the work, and it is usually left soft. The dead center and live center must NEVER be interchanged. (There is a groove around the hardened dead center to distinguish it from the live center.)

The centers fit snugly in the tapered holes of the headstock and tailstock spindles. If chips, dirt, or burrs prevent a perfect fit in the spindles, the centers will not run true.

To remove the headstock center, inset a brass rod through the spindle hole and tap the center to jar it loose; it can then be picked out with the hand. To remove the tailstock center, run the spindle back as far as it will go by turning the handwheel to the left. When the end of the tailstock screw bumps the back of center, it will force it out of the tapered hole.

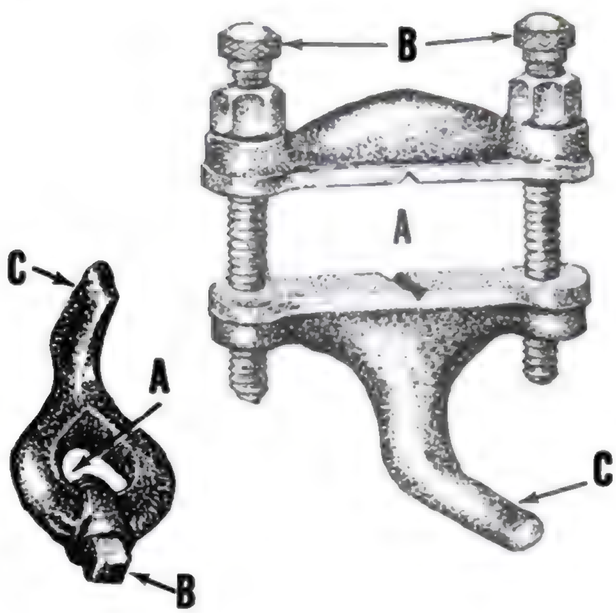


28.93
Figure 18-10.—Sixty-degree lathe centers.

Lathe Dogs

Lathe dogs are used in conjunction with a driving plate or faceplate to drive work being machined on centers, the frictional contact alone between the live center and the work not being sufficient to drive it.

The common lathe dog, shown at the left in figure 18-11, is used for round work or work having a regular section (square, hexagon, octagon). The piece to be turned is held firmly in hole A by setscrew B. The bent tail C projects through a slot or hole in the driving plate or faceplate, so that when the latter revolves with the spindle it turns the work with it. The clamp dog, illustrated in figure 18-11, may be used for rectangular or irregular shaped work. Such work is clamped between the jaws.



28.95X
Figure 18-11.—Lathe dogs.

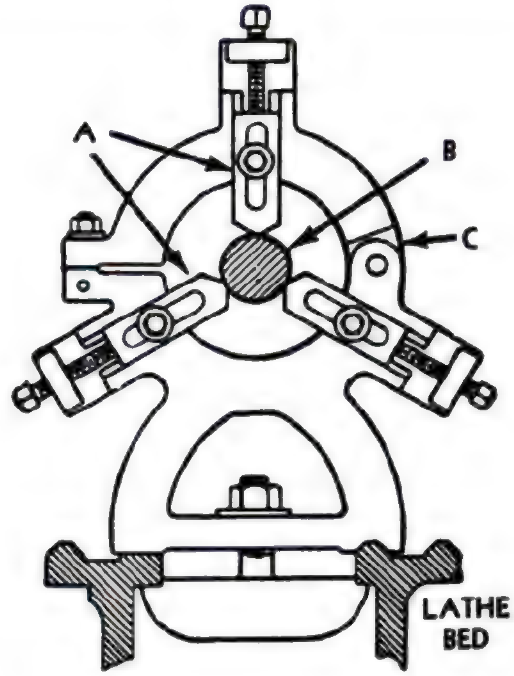


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Figure 18-12.—Center rest.

Center Rest

The center rest, also called the steady rest, is used for the following purposes:

1. To provide an intermediate support or rest for long slender bars or shafts being machined between centers. It prevents them from springing under cut, or sagging as a result of their otherwise unsupported weight.

2. To support and provide a center bearing for one end of work, such as a spindle, being bored or drilled from the end when it is too long to be supported by a chuck alone. The center rest is clamped in the desired position on the bed, on which it is properly aligned by the ways, as illustrated in figure 18-12. It is important that the jaws (A) be carefully adjusted to allow the work (B) to turn freely and at the same time keep it accurately centered on the axis of the lathe. The top half of the frame is hinged at C to facilitate placing it is position without removing the work from the centers or changing the position of the jaws.

Follower Rest

The follower rest is used to back up work of small diameter to keep it from springing

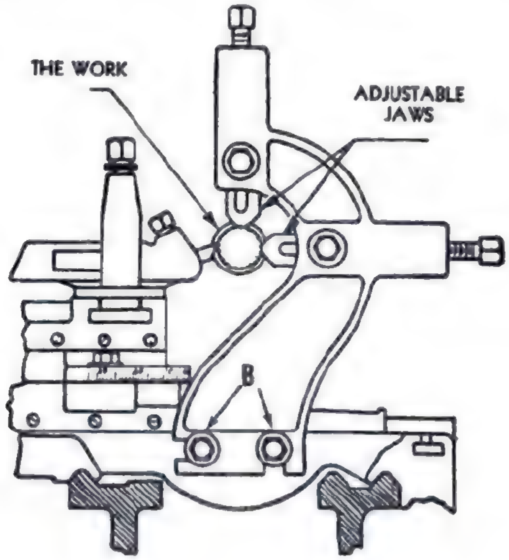

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Figure 18-13.—Follower rest.

under the stress of cutting. It gets its name from the fact it follows the cutting tool along the work. As shown in figure 18-13, it is attached directly to the saddle by bolts (B). The adjustable jaws bear directly on the finished diameter of the work opposite the cutting tool.

Taper Attachment

The taper attachment, illustrated in figure 18-14, is used for turning and boring tapers. It is bolted to the back of the carriage saddle. In operation, it is so connected to the cross-slide that it moves the cross-slide laterally as the carriage moves longitudinally, thereby causing the cutting tool to move at an angle to the axis of the work to produce a taper.

The angle of the taper it is desired to cut is set on the guide bar of the attachment. The guide bar support is clamped to the lathe bed.

Since the cross-slide is connected to a shoe that slides on this guide bar, the tool follows along a line that is parallel to the guide bar and hence at an angle to the work axis corresponding to the desired taper.

The operation and application of the taper attachment will be further explained under the subject of taper work.

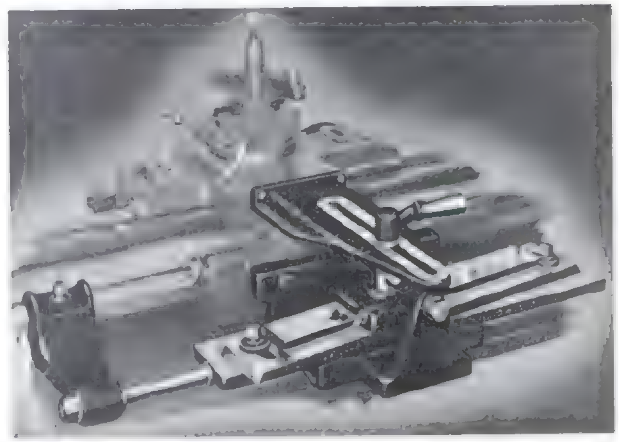

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Figure 18-14.—A taper attachment.

Thread Dial Indicator

The thread dial indicator, shown in figure 18-15, eliminates the necessity of reversing the lathe to return the carriage to the starting point to catch the thread at the beginning of each successive cut that is taken. The dial, which is geared to the lead screw, indicates when to clamp the half-nuts on the lead screw for the next cut.

The threading dial consists of a worm wheel which is attached to the lower end of a shaft and meshed with the lead screw. On the upper end of the shaft is the dial. As the lead screw revolves, the dial is turned and the graduations on the dial indicate points at which the half-nuts may be engaged.

Carriage Stop

The carriage stop can be attached to the bed at any point where it is desired to stop the carriage. It is used principally when turning, facing, or boring duplicate parts, as it eliminates the necessity of repeated measurements of the same dimension. In operation, the stop is set at the point where it is desired to stop the feed. Just before reaching this point, the operator shuts off the automatic feed and carefully runs the carriage up against the stop. Carriage stops are provided with or without micrometer adjustment. Figure 18-16 shows a micrometer carriage stop. It is clamped on the ways in the approximate position required and then adjusted to the exact setting by means of the micrometer adjustment. (Do not confuse this stop with automatic carriage

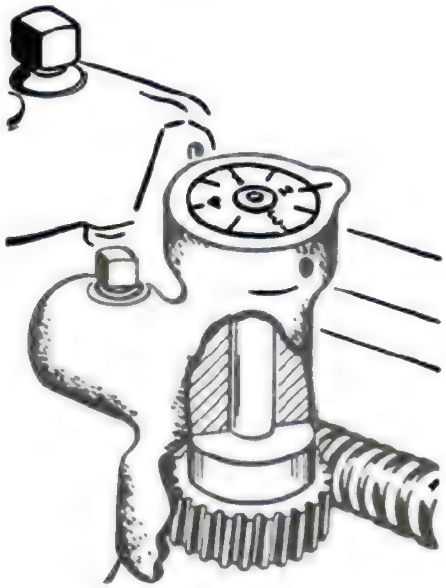

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Figure 18-15.—Thread dial indicator.

stop that automatically stops the carriage by disengaging the feed or stopping the lathe.)

FACTORS RELATED TO MACHINING OPERATIONS

A knowledge of many factors is required if you are to be proficient in performing machine work with a lathe. Some of these factors are considered in the following sections.

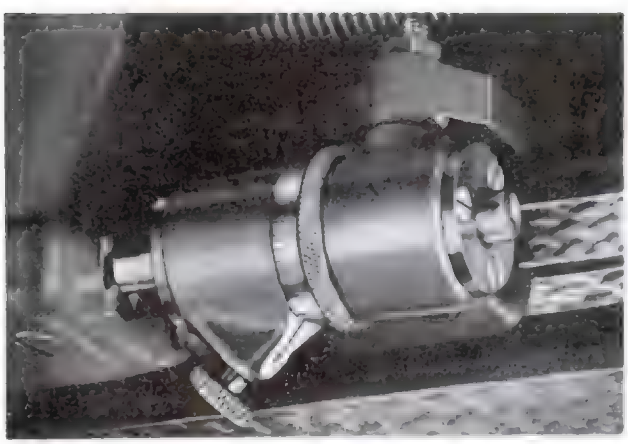

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Figure 18-16.—Micrometer carriage stop.

PHASES OF THE OPERATION

Before attempting the operation of any lathe, make sure you know how to run it. Read all operating instructions supplied with the machine. Ascertain the location of the various controls and how to operate them. When you are satisfied that you know how they work, start the motor, but first check to see that the spindle clutch and the power feeds are disengaged. Then become familiar with all phases of operation, as follows:

1. Shift the speed change levers into the various combinations; start and stop the spindle after each change. Get the feel of this operation.
2. With the spindle running at its slowest speed, try out the operation of the power feeds and observe their action. Take care not to run the carriage too near the limits of its travel. Learn how to reverse the direction of feeds and how to disengage them quickly. Before engaging either of the power feeds, operate the hand controls to be sure parts involved are free for running.
3. Try out the operation of engaging the lead screw for thread cutting. Remember that the feed mechanism must be disengaged before the half-nuts can be closed on the lead screw.
4. Practice making changes with the QUICK-CHANGE GEAR MECHANISM by referring to thread and feed index plate on the lathe you intend to operate. Remember that changes in the gear box are done with the lathe running slowly, but the lathe must be stopped for large changes made by shifting gears in the main gear train.

MAINTENANCE

Maintenance is an important part of operational procedure for lathes. As a Machinist's Mate, you will be expected to assist in the proper maintenance and preservation of the machine and the spaces.

The Maintenance and Material Management (3-M) System has been implemented in the Navy as an answer to the ever present problem of maintaining a high degree of operational readiness. A thorough study of Military Requirements for Petty Officers 3 & 2, NAVPERS 10056-C will provide you with all the information you need on the 3-M System.

Although the 3-M System is designed to improve the degree of readiness, its effectiveness and reliability are dependent upon you, the individual. The accuracy with which you perform your work, along with the neat and complete recording of required data on the prescribed forms is one of the keys to the degree of readiness of your ship.

Table 18-1.—Cutting Speeds with High Speed Steel Tool Bits

Type of metal	Roughing cut	Finishing cut	Thread-cutting
	Feet per minute (fpm)		
Cast iron	60	80	25
Machine steel	90	125	35
Tool steel	50	75	20
Brass	150	200	50
Bronze	90	100	25
Aluminum	200	300	50

28.292

Remember PREVENTIVE MAINTENANCE (scheduled checks) will lead to less CORRECTIVE MAINTENANCE (repair of equipment). Control over rust and corrosion will be a major problem. Equipment used often is not likely to "freeze up," but machinery which is seldom used may fail to operate at a crucial moment. It is a good policy to check and operate all machinery immediately after the weekly lubrication.

There will be rust-film trouble in all climates, but more frequently in the tropics because of humidity (moisture). All bare metal surfaces should be kept clean and bright, and a light coat of machine oil should be applied to protect them. The rust-prevention program should be a part of your daily cleanup routine. Using an approved rust-preventive compound will help prevent rusting of decks and bare metal surfaces and machinery parts.

It is sometimes said that a machine tool operator can be judged by the condition of his tools, machines, and spaces. Good maintenance practices will save you many hours of extra work.

Keep your lathe CLEAN. A clean and orderly machine is an indication of a good mechanic. Dirt and chips on the ways, on the lead screw, and on the crossfeed screws will cause serious wear and impair the accuracy of the machine.

Never put wrenches, files, or other tools on the ways. If you must keep tools on the bed, a board should be provided to protect the finished surfaces of the ways.

Never use the bed or carriage as an anvil; remember that the lathe is a precision machine and nothing must be allowed to destroy its accuracy.

CUTTING SPEEDS AND FEEDS

CUTTING SPEED is the rate at which the surface of the work passes the point of the cutting tool. It is expressed in feet per minute.

To find the cutting speed, multiply the circumference of the work (in inches) by the number of revolutions it makes per minute (rpm) and divide by 12. (Circumference = diameter x 3.1416.) The result is the peripheral or cutting speed in feet per minute (fpm). For example, a 2-inch diameter piece turning at 100 rpm will produce a cutting speed (CS) of

$$\frac{D \times \pi \times rpm}{12} = CS$$

$$\frac{(2 \times 3.1416) \times 100}{12} = 52.36 \text{ fpm}$$

Conversely, the rpm required to obtain a given cutting speed is found by dividing the product of the given cutting speed and 12 by the circumference of the work (in inches).

$$\frac{CS \times 12}{\pi \times D} = rpm$$

FEED is the amount the tool advances in each revolution of the work. It is usually expressed in thousandths of an inch per revolution of the spindle. The index plate on the quick-change gear box indicates the setup for obtaining the feed desired. The amount of feed to use is best determined from experience.

Cutting speeds and tool feeds are determined by various considerations: the hardness and toughness of the metal being cut; the quality, shape, and sharpness of the cutting tool; the depth of the cut; the tendency of the work to spring away from the tool, and the strength and power of the lathe. Since conditions vary, it is good practice to find out what the tool and work will stand, and then select the most practicable and efficient speed and feed consistent with the finish desired.

If the cutting speed is too slow, the job takes longer than necessary and often the work produced is unsatisfactory. On the other hand, if the speed is too great, the tool edge will dull quickly, and frequent grinding will be necessary. The cutting speeds possible are greatly affected by the use of a suitable cutting lubricant. For example, steel which can be rough turned dry at 60 rpm can be turned at about 80 rpm when flooded with a good cutting lubricant.

Table 18-1 gives the approximate recommended cutting speeds for different metals, using high-speed steel tool bits. Figures indicate feet per minute (fpm).

When ROUGHING parts down to size, use the greatest depth of cut and feed per revolution that the work, the machine, and the tool will stand at the highest practicable speed. On many pieces where tool failure is the limiting factor in the size of roughing cut, it is usually possible to reduce the speed slightly and increase the feed to a point where the metal removed is much greater. This will prolong tool life. Consider an example where the depth of cut is 1/4 inch, the feed 20 thousandths of an inch per revolution, and the speed 80 fpm. If the tool will not permit additional feed at this speed, it is usually possible to drop the speed to 60 fpm and increase the feed to about 40 thousandths of an inch per revolution without having tool trouble. The speed is, therefore, reduced 25 percent but the feed increased 100 percent, so that the actual time required to complete the work is less with the second setup.

On the FINISH TURNING OPERATION a very light cut is taken, since most of the stock has been removed on the roughing cut. A fine feed can usually be used, making it possible to run at a high surface speed. A 50-percent increase in speed over the roughing speed is commonly used. In particular cases the finishing speed may be twice the roughing speed. In any event, the work should be run as fast as the tool will withstand to obtain the maximum speed in this operation. A sharp tool should be used when finish turning.

COOLANTS

A cutting lubricant serves two main purposes—it cools the tool by absorbing a portion of the heat and reduces the friction between the tool and the metal being cut. A secondary purpose is to keep the cutting edge of the tool flushed clean.

The best lubricants to use for cutting metal must often be determined by experiment. Ordinary oil is often used, but soapy water or soda water is better for iron and steel shafting and if used in conjunction with a sharp tool and light finish cut, the work will be smooth enough to polish without filing. Other cutting lubricants are mineral lard oil, kerosene, and turpentine. Special cutting compounds containing such ingredients as tallow, graphite, and white lead, marketed under various names, are also used, but these are expensive and used mainly in manufacturing where high cutting speeds are the rule.

The usual lubricants for turning the following metals are:

Metal	Lubricant
Cast iron	Usually worked dry.
Mild steel	Oil or soapy water.
Hard steel	Mineral lard oil.
Monel metal	Dry (or mineral lard oil).
Bronze	Dry (or mineral lard oil).
Brass	Dry (kerosene or turpentine sometimes used on the hard compositions).
Copper	Dry (or mixture of lard oil and turpentine).
Babbitt	Dry (or mixture of lard oil and kerosene).
Aluminum	Dry (or kerosene or mixture of lard oil and kerosene).

For threading, a lubricant is more important than for straight turning. Mineral lard oil is recommended for threading in all steels and cast iron, kerosene mixed with oil for aluminum, white lead mixed with oil (to the consistency of glue) for Monel metal, and kerosene or turpentine for brass compositions.

CHATTER

If you are unaware of the meaning of the word "chatter," you will learn all too soon while working with a machine tool of any description.

Briefly, chatter is vibration in either the tool or the work. The finished work surface appears to have a grooved or lined finish instead of the smooth surface that is to be expected. The vibration is set up by a weakness in the work, work support, tool, or tool support, and is about the most elusive thing to find in the entire field of machine work. As a general rule, strengthening the various parts of the tool support train will help. It is also advisable to support the work by a center rest or follower rest.

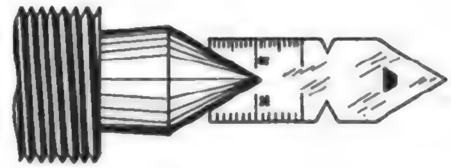
Possibly the fault may be in the machine adjustments. Gibs may be too loose; bearings may, after a long period of heavy service, be worn; the tool may be sharpened improperly, etc. If the machine is in excellent condition, the fault may be in the tool or tool setup. Grind the tool with a point or as near a point as the finish specified will permit; avoid a wide round leading edge on the tool. Reduce the overhang of the tool as much as possible and be sure that all the gib and bearing adjustments are properly made. See that the work receives proper support for the cut, and, above all, do not try to turn at a surface speed that is too high. Excessive speed is probably the greatest cause of chatter, and the first thing you should do when chatter occurs is to reduce the speed.

DIRECTION OF FEED

Regardless of how the work is held in the lathe, the tool should feed toward the headstock. This results in most of the pressure of the cut being exerted on the workholding device and spindle thrust bearings. When it is necessary to feed the cutting tool toward the tailstock, take lighter cuts at reduced feeds. In facing, the general practice is to feed the tool from the center of the workpiece out toward the periphery.

PRELIMINARY PROCEDURES

Before starting a lathe machining operation, always ensure that the machine is set up for the job you are doing. If the work is mounted between centers, check the alignment of the dead center with the live center and make any changes required. Ensure that the toolholder and cutting tool are set at the proper height and angle. Check the workholding accessory to ensure that the workpiece is held securely. Use the center rest or follower rest for support of long workpieces.

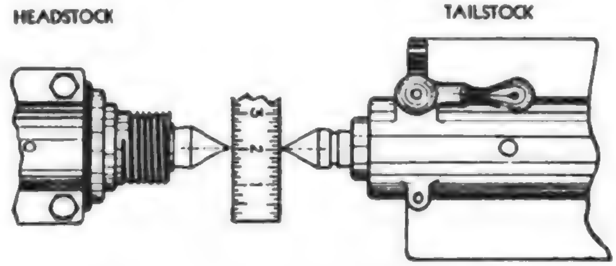


28.105X
Figure 18-17.—Checking center point with center gage.

PREPARING THE CENTERS

The first step in preparing the centers is to see that they are accurately mounted in the headstock and tailstock spindles. The centers and the tapered holes in which they are fitted must be perfectly clean. Chips and dirt left on the contact surfaces will impair accuracy by preventing a perfect fit of the bearing surfaces. Make sure that there are no burrs in the spindle hole. If burrs are found they should be removed by careful scraping or reaming with a Morse taper reamer. Burrs will produce the same inaccuracies as chips or dirt.

Center points must be accurately finished to an angle of 60°. Figure 18-17 shows the method of checking this angle with a center gage. The large notch of the center gage is intended for this particular purpose. If this test shows that the point is not perfect it must be trued in the lathe by taking a cut over the point with the compound rest set at 30°. The hardened tail center must be annealed before it can be machined in this manner, or it can be ground if a grinding attachment is available.



28.106
Figure 18-18.—Aligning lathe centers.

CHECKING ALIGNMENT

To turn a shaft straight and true between centers, it is necessary that the centers be in a plane parallel to the ways of the lathe. The tailstock may be moved laterally to accomplish this alignment by means of two adjusting screws after it has been released from the ways. At the rear of the tailstock are two zero lines, and the centers are approximately aligned when these lines coincide. This approximate alignment may be checked by moving the tailstock up until the centers almost touch, and observing their relative positions as shown in figure 18-18. For very accurate work, especially if it is long, the following test is necessary to correct small errors in alignment not otherwise detected.

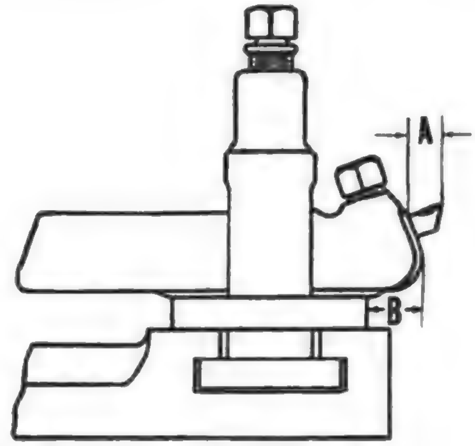
The work to be turned, or a piece of stock of similar length, is mounted on the centers. With a turning tool in the tool post, take a small cut to a depth of a few thousandths of an inch at the headstock end of the work. Then remove the work from the centers to allow the carriage to be run back to the tailstock without withdrawing the tool. Do not touch the tool setting. Replace the work in the centers, and with the tool set at the previous depth take another cut coming in from the tailstock end. Compare the diameters over these cuts with a micrometer. If the diameters are exactly the same, the centers are in perfect alignment. If they are different, the tailstock must be adjusted in the direction required by means of the set-over adjusting screws. Repeat the above test and adjustments until a cut at each end produces equal diameter.

Positive alignment of centers may also be checked by placing a test bar between centers and bringing both ends of the bar to a zero reading as indicated by a dial indicator clamped in the tool post. The tailstock must be clamped to the ways and the test bar properly adjusted between centers when taking the indicator readings.

Another method that may be used for positive alignment of lathe centers is to take a light cut over the work held between centers. Then measure the work at each end with a micrometer, and if the readings are found to differ, adjust the tailstock accordingly. Repeat the procedure until alignment is obtained.

SETTING THE TOOLHOLDER AND CUTTING TOOL

The first requirement for setting the tool is to have it rigid. Make sure the tool sets squarely in the tool post and that the setscrew is tight.



28.110X
Figure 18-19.—Tool overhang.

Reduce overhang as much as possible to prevent springing when cutting. If the tool has too much spring, the point of the tool will catch in the work, causing chatter and damaging both the tool and the work. The distances represented by A and B in figure 18-19 show the correct overhang for the tool bit and the holder.

The point of the tool must be correctly positioned on the work. The cutting edge is placed exactly on the center for all other work. To set the tool on center raise or lower the point of the tool by moving the wedge in or out of the tool post ring. By placing the point opposite the tail center point, the setting can be accurately adjusted.

HOLDING THE WORK

Accurate work cannot be performed if work is improperly mounted. Requirements for proper mounting are:

1. The work center line must be accurately centered with the axis of the lathe spindle.

2. The work must be rigidly held while being turned.

3. The work must not be sprung out of shape by the holding device.

4. The work must be adequately supported against any sagging caused by its own weight and against springing caused by the action of the cutting tool.

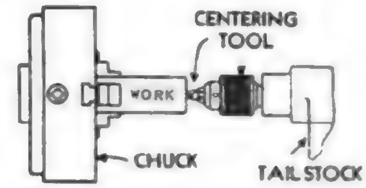
There are four general methods of holding work in the lathe: (1) between centers, (2) on a mandrel, (3) in a chuck, and (4) on a faceplate. Work may also be clamped to the carriage for boring and milling, in which case the boring bar or milling cutter is held and driven by the headstock spindle.

Other methods of holding work to suit special conditions are: (1) one end on the live center or in a chuck and the other end supported in a center rest, and (2) one end in a chuck and the other end on the dead center.

Holding Work Between Centers

To machine a workpiece between centers, center holes must be drilled in each end to receive the lathe centers. A lathe dog is then secured to the workpiece and then the work is mounted between the live and dead centers of the lathe.

CENTERING THE WORK.—To center finished round stock such as drill rod or cold-rolled steel, where the ends are to be turned and must be concentric with the unturned body, the work can be held on the head spindle in a universal chuck or a draw-in collet chuck. If the work is long and too large to be passed through the spindle, a center rest must be used to support one end. The centering tool is held in a drill chuck in the tail spindle and is fed to the work by the tailstock handwheel (fig. 18-20).



28.111
Figure 18-20.—Drilling center hole.

If a piece must be centered very accurately, the tapered center hole should be bored after center drilling to correct any run-out of the drill. This is done by grinding a tool bit to a center gage at a 60° angle. Then with the toolholder held in the tool post, set the compound rest at 30° with the line of center as shown in figure 18-21. Set the tool exactly on the center for height and adjust to the proper angle with the center gage as shown at A. By feeding the tool as shown at B, any run-out of the center is corrected. The tool bit should be relieved under the cutting edge as shown at C to prevent the tool from dragging or rubbing in the hole.

For centerdrilling a workpiece, the combined drill and countersink is the most practical tool. These combined drills and countersinks vary in size and the drill points also vary. Sometimes a drill point on one end will be 1/8 inch in diameter, the drill point on the opposite end 3/16 inch in diameter. The angle of the centerdrill is always 60° so that the countersunk hole will fit the angle of the lathe center point.

If a centerdrill is not available, the work may be centered with a small twist drill. Let the drill enter the work a sufficient length on each end; then follow with a special countersink, the point of which is 60°.

In centerdrilling, a drop or two of oil should be used on the drill. The drill should be fed slowly and carefully so as not to break the tip. Extreme care is needed when the work is heavy, because it is then more difficult to "feel" the proper feed of the work on the center drill.

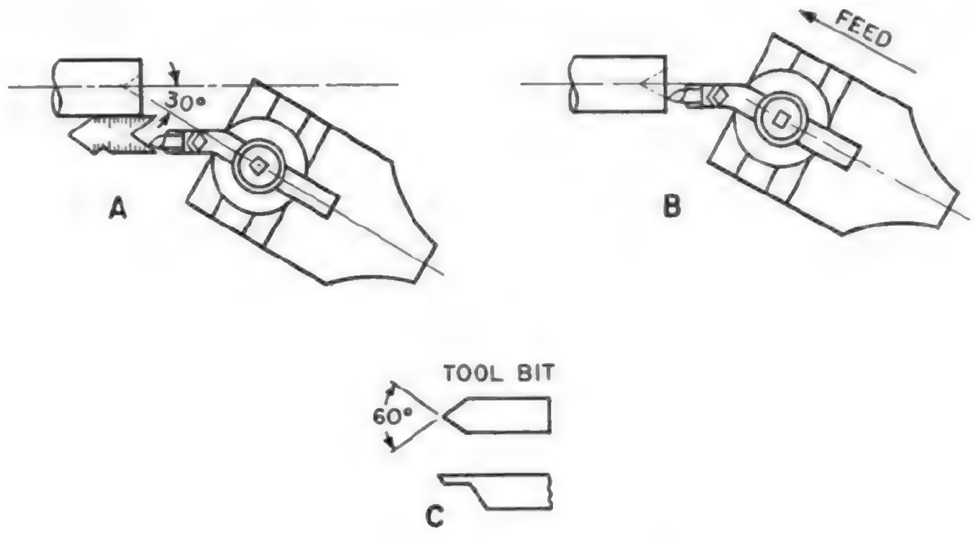
If the center drill breaks while countersinking and part of the broken drill remains in the work, this part must be removed. Sometimes it can be driven out by a chisel or jarred loose, but it may stick so hard that it cannot be removed. Then the broken part of the drill should be annealed and drilled out.

The importance of proper center holes in the work and a correct angle on the point of the lathe centers cannot be overemphasized. To do an accurate job between centers on the lathe, countersunk holes must be of the proper size and depth, and the points of the lathe centers must be true and accurate.

MOUNTING THE WORK.—Figure 18-22 shows correct and incorrect methods of mounting work between centers. In the correct example, the driving dog is attached to the work and rigidly held by the setscrew. The tail of the dog rests in the slot of the faceplate and extends beyond the base of the slot so that the work rests firmly on both the headstock center and tailstock center.

In the incorrect example, note that the tail of the dog rests on the bottom of the slot on the faceplate at A, thereby pulling the work away from the center points, as shown at B and C, and causing the work to revolve eccentrically.

When mounting work between centers for machining, there should be no end play between the work and the dead center. However, if the work is held too tightly by the tail center when revolving, the work will heat the center point, destroying both the center and the work. To help prevent overheating, the tail center must be



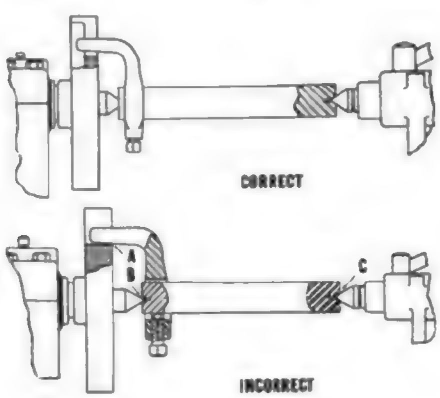
28.112
Figure 18-21.—Boring center hole.

lubricating with a heavy mixture of white lead and oil.

Holding Work on a Mandrel

Many parts, such as bushings, gears, collars, and pulleys, require all the finished external surfaces to run true with the hole which extends through them, That is, the outside diameter must be ture with the inside diameter or bore.

General practice is to finish the hole to a standard size, within the limit of the accuracy desired. Thus a 3/4-inch standard hole would ordinarily be held from 0.7505 inch or a tolerance of one-half thousandth of an inch above or below the true standard size of exactly 0.750 inch.

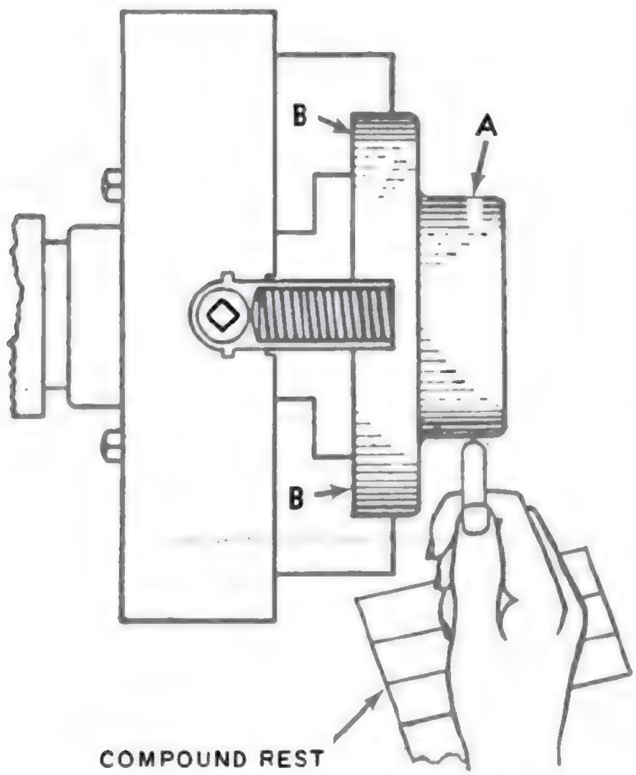


28.115X
Figure 18-22.—Examples of work mounted between centers.

First drill or bore the hole to within a few thousandths of an inch of the finished size; then remove the remainder of the material with a machine reamer, following with a hand reamer if the limits are extremely close.

The piece is then pressed on a mandrel tight enough so the work will not slip while being machined. A dog is clamped on the mandrel, which is mounted between centers. Since the mandrel surface runs true with respect to the lathe axis, the turned surfaces of the work on the mandrel will be true with respect to the hole in the piece.

A mandrel is simply a round piece of steel of convenient length which has been centered and turned true with the centers. Commercial mandrels are made of tool steel, hardened and ground with a slight taper (usually 0.0005 inch per inch). On sizes up to 1 inch the small end is usually one-half thousandth of an inch under the standard size of the mandrel, while on larger sizes this dimension is usually one thousandth of an inch under standard. This taper allows the standard hold in the work to vary according to the usual shop practice, and still provides a drive to the work when the mandrel is pressed into the hole. The taper is not great enough to distort the hole in the work. The countersunk centers of the mandrel are lapped for accuracy. The ends are turned smaller than the body of the mandrel and provided with flats which give a driving surface for the lathe dog.



28.119
Figure 18-23.—Work mounted in a Four-jaw chuck.

Holding Work in Chucks

The independent check and universal chuck are more often used than other workholding devices in performing lathe operations. The universal chuck is used for holding relatively true cylindrical work when accurate concentricity of the machined surface and holding power of the chuck is secondary to time required to do the job. When the work is irregular in shape, must be accurately centered, and must be held securely for heavy feeds and depth of cuts, the independent chuck should be used.

FOUR-JAW INDEPENDENT CHUCK.—Figure 18-23 shows a rough casting mounted in a four-jaw independent lathe chuck on the spindle of the lathe. Before truing the work, determine which part you wish to have turn true. To mount this casting in the chuck, proceed as follows:

1. Adjust the chuck jaws to receive the casting. Each jaw should be concentric with the ring marks indicated on the face of the chuck. If there are no ring marks, be guided by the circumference of the body of the chuck.

2. Fasten the work in the chuck by turning the adjusting screw on jaw No. 1 and jaw No. 3, a pair of jaws which are opposite each other. Next tighten jaws No. 2 and No. 4.

3. At this stage the work should be held in the jaws just tight enough so it will not fall out of the chuck while being trued.

4. Revolve the spindle slowly and, with a piece of chalk, mark the high spot (A in fig. 18-23) on the work while it is revolving. Steady your hand on the tool post while holding the chalk.

5. Stop the spindle. Locate the high spot on the work and adjust the jaws in the proper direction to true the work by releasing the jaw opposite the chalk mark and tightening the mark.

6. Sometimes the high spot on the work will be located between adjacent jaws. In that case, loosen the two opposite jaws and tighten the jaws adjacent to the high spot.

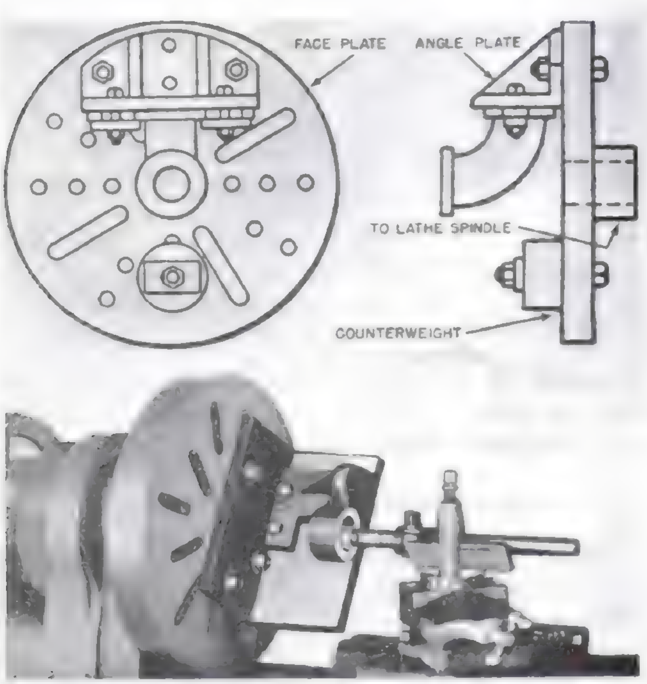
THREE-JAW UNIVERSAL CHUCK.—The three-jaw universal or scroll chuck is made so that all jaws move together or apart in unison. A universal chuck will center almost exactly at the first clamping, but after a period of use it is not uncommon to find inaccuracies of from 2 to 10 thousandths of an inch in centering the work, and consequently the run-out of the work must be corrected. Sometimes this may be done by inserting a piece of paper or thin shim stock between the jaw and the work on the high side.

After the positioning has been done in a chuck, be sure to tighten all the screws so that each jaw is tight against the piece to prevent it from slipping under cut.

When chucking thin sections, be careful not to clamp the work too tightly, as then the diameter of the piece will be machined when it is in a distorted position. When the pressure of the jaws is released after the cut, there will be as many high spots as there are jaws, and the turned surface will not be true.

CARE OF CHUCKS.—To preserve a chuck's accuracy, handle it carefully and keep it clean and free from grit. Never force a chuck jaw by using a pipe as an extension on the chuck wrench.

Before mounting a chuck, remove the live center and fill the hole with a rag to prevent chips and dirt from getting into the taper hole of the spindle. Removal of the center is necessary to prevent the possibility of its being ruined when drilling work held in the chuck; the operator may inadvertently drill right through the center.



28.124X
Figure 18-24.—Work clamped to an angle plate.

Clean and oil the threads of the chuck and the spindle nose. Dirt or chips on the threads will not allow the chuck to run true when it is screwed up to the shoulder. Screw the chuck on carefully. Avoid bringing it up against the shoulder so fast that the chuck comes up with a shock since this will strain the spindle and the threads and make removal difficult. Never use mechanical power in screwing on the chuck. Rotate the spindle with the left hand while holding the chuck in the hollow of the right arm.

To remove a small chuck, place an adjustable jaw wrench on one of the jaws and start it by a smart blow with the hand on the handle of the wrench. To remove a heavy chuck, rotate it against a block of wood held between a jaw and the lathe bed. When mounting or removing a heavy chuck, lay a board across the bed ways to protect them; the board will serve as a support for the chuck as it is put on or taken off.

The above comments on mounting and removing chucks also apply to faceplates.

Holding Work on a Faceplate

A faceplate is used for mounting work which cannot be chucked or turned between centers. This may occur because of the peculiar shape of the work. A faceplate may be used when holes are to be accurately machined in flat work, or when large and irregularly shaped work is to be faced on the lathe.

Work is secured to the faceplate by bolts, clamps, or any suitable clamping means. The holes and slots in the faceplate are used for anchoring the holding bolts. Angle plates may be used to present the work at the desired angle, as shown in figure 18-24.

Note the counterweight added for balance.

For work to be mounted accurately on a faceplate, the surface of the work in contact with the faceplate must be accurately faced. For very accurate work, the faceplate itself should be refaced by taking a light cut over its surface. It is good practice to place a piece of paper between the work and the faceplate to prevent slipping.

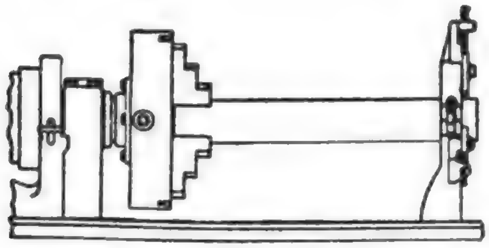
Before securely clamping the work, it must be moved about on the surface of the faceplate until the point to be machined is centered accurately over the axis of the lathe. Suppose you wish to bore a hole, the center of which has been laid out and marked with a prick punch. First clamp the work to the approximate position on the faceplate. Then prepare a rod with a countersunk center hold to fit the tailstock center at one end, and with an accurate center point on the other end. Slide the tailstock up and place the rod with the point in the prick-punch mark on the work and the other end on the tail center. Then revolve the work slowly. If the punch mark is off center, the point of the rod will describe a small circle (appear to wobble); if it is right on center the rod will remain stationary. For very accurate centering, a dial indicator held in the tool post and applied to the rod will indicate a very small movement of the rod (to a thousandth of an inch).

Using the Center Rest and Follower Rest

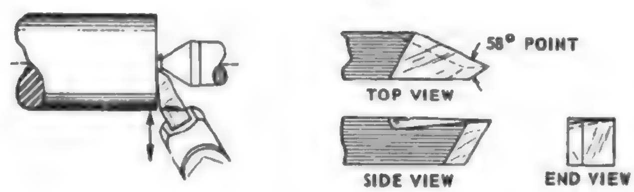
In addition to being supported at the ends by the lathe centers, long slender work often requires support between ends while being turned; otherwise the work would spring away from the tool and chatter. The center rest is used to support such work so it can be accurately turned with a faster feed and cutting speed than would be possible without it.

The center rest should be placed where it will give the greatest support to the piece to be turned. This is usually at about the middle of its length.

Ensure that the center point between the jaws of the center rest coincides exactly with the axis of the lathe spindle. To do this, place a short piece of stock in a chuck and machine it to the diameter of the workpiece to be supported. Without removing



28.126X
Figure 18-25.—Work mounted in a chuck and center rest.



28.129X
Figure 18-26.—Facing a cylindrical piece.

the stock from the chuck, clamp the center rest on the ways of the lathe and adjust the jaws to the machined surface. Without changing the jaw settings, slide the center rest into position for supporting the workpiece. Remove the stock used for setting the center rest and set the workpiece in place. Use a dial indicator to true the workpiece at the chuck. Figure 18-25 shows how a chuck and center rest are used when machining the end of a workpiece.

The follower rest differs from the center rest in that it moves with the carriage and provides support against the forces of the cut only. The tool should be set to the diameter selected and a "spot" turned about 5/8 to 3/4 inch wide. Then the follower rest jaws should be adjusted to the finished diameter to follow the tool along the entire length to be turned.

Use a thick mixture of white lead and oil on the jaws of the center rest and follower rest to prevent "seizing" and scoring the workpiece. Check the jaws frequently to see that they do not become hot. The jaws may expand slightly if they get hot thus pushing the work out of alignment (when using the follower rest) or binding (when using the center rest).

Holding Work in a Draw-In Collet Chuck

The draw-in collet chuck is used for very fine accurate work of small diameter. Long work can be passed through the hollow drawbar, and short work can be placed directly into the collet from the front. The collet is tightened on the work by rotating the drawbar to the right; this draws the collet into the tapered closing sleeve. The opposite operation releases the collet.

Accurate results are obtained when the diameter of the work is exactly the same size as the dimension stamped on the collet. In some cases, the diameter may vary as much as 0.002 inch; that is, the work may be 0.001 inch smaller or larger than the collet size. If the work diameter varies more than this, it will impair the accuracy and efficiency of the collet. That is why a separate collet should be used for each small variation of work diameter, especially if precision is desired.

MACHINING OPERATIONS

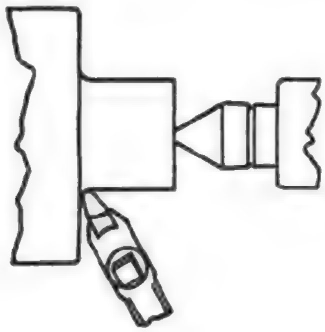
Up to this point you have studied the preliminary steps leading up to the performance of machine work in the lathe. You have learned how to mount the work and the tool, and which tools are used for various purposes. Now, to be considered is the method of using the proper tools in combination with the lathe to perform various machining operations.

FACING

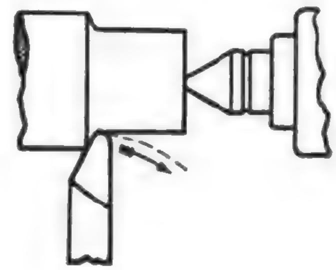
Facing is the machining of the end surfaces and shoulders of a workpiece. In addition to squaring the ends of the work, facing provides a means of accurately cutting the work to length. Generally in facing the workpiece, only light cuts are required as the work will have been cut to approximate length or rough machined to the shoulder.

Figure 18-26 shows the method of facing a cylindrical piece. The work is placed on centers and driven by a dog. A right hand side tool is used as shown, and a light cut is taken on the end of the work, feeding the tool (by hand crossfeed) from the center toward the outside. One or two cuts are taken to remove sufficient stock to true the work. Then the dog is placed on the other end of the work and faced to the proper length. A steel rule is used to measure off the length. Another rule or straightedge held on the end that has just been faced provides an accurate base from which to measure. Be sure there is no fin or burr on the edge to keep the straightedge from bearing accurately on the finished end. Use a sharp scriber to mark off the dimension desired.

Figure 18-27 shows the application of a turning tool in finishing a shouldered job having a fillet



28.130X
Figure 18-27.—Facing a shoulder.



28.132X
Figure 18-28.—Position of tool for heavy cut.

corner. A finish cut is taken on the small diameter. The fillet is machined with a light cut; then the tool is used to face from the fillet to the outside diameter of the work.

In facing large surfaces the carriage should be locked in position, since only crossfeed is required to traverse the tool across the work. With the compound rest set at 90° (parallel to the axis of the lathe), the micrometer collar can be used to feed the tool to the proper depth of cut in the face. For greater accuracy in obtaining a given size in finishing a face, the compound rest may be set at 30°. In this position, one-thousandth of an inch movement of the compound rest will move the tool exactly one-half thousandth of an inch in a direction parallel to the axis of the lathe. In a 30°-60°-90° right triangle, the length of the side opposite the 30° angle is equal to one-half the length of the hypotenuse.)

TURNING

Turning is the machining of excess stock from the periphery of the workpiece to reduce the diameter. In most lathe machining requiring removal of large amounts of stock, a series of roughing cuts is taken to remove most of the excess stock; then a finishing cut is taken to accurately "size" the workpiece.

Rough Turning

When a great deal of stock is to be removed, heavy cuts should be taken in order to complete the job in the least possible time. This is called rough turning.

The proper tool should be selected for taking a heavy cut. The speed of the work, and the amount of feed of the tool should be as great as the tool will stand.

When taking a roughing cut on steel, cast iron, or any other metal that has a scale upon its surface, be sure to set the tool deep enough to get under the scale in the first cut. Unless you do, the scale on the metal will dull the point of the tool.

The work should be rough machined to almost the finished size; then care in measuring is required.

Bear in mind the fact that the diameter of the work being turned is reduced by an amount equal to twice the depth of the cut; thus, if you desire to reduce the diameter of a piece by one-fourth of an inch, one-eighth of an inch of metal must be removed from the surface.

Figure 18-28 shows the position of the tool for taking a heavy cut on large work. The tool should be set so that if anything occurs while machining to change the position of the tool, it will not dig into the work, but rather it will move in the direction of the arrow-away from the work.

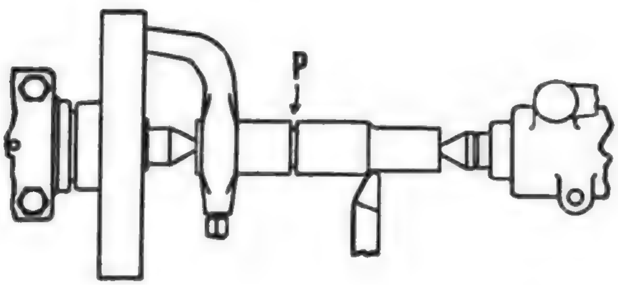
Finish Turning

When the work has been rough turned to within about 1/32 inch of the finished size, take a finishing cut. A fine feed, the proper lubricant, and above all a keen-edged tool are necessary to produce a smooth finish. Measure carefully to be sure that you are machining the work to the proper dimension. Stop the lathe when measuring with micrometers.

Where very close limits are to be held, it is advisable to see that the work is not hot when the finish cut is taken. Cooling of the piece will leave it undersized if it has been turned to the exact size.

On work that is to be finished by a cylindrical grinder, a limited amount of stock is usually left for grinding to the finished dimensions.

Perhaps the most difficult operation for a beginner in machine work is to make accurate measurements. So much depends on the accuracy of the work that you should make every effort to become proficient in the use of measuring



28.133X
Figure 18-29.—Machining to a shoulder.

instruments. A certain "feel" in the application of micrometers is developed through experience alone; do not be discouraged if your first efforts produce imperfect results. Practice taking micrometer measurements on pieces of known dimensions. You will acquire skill if you are persistent.

Turning to a Shoulder

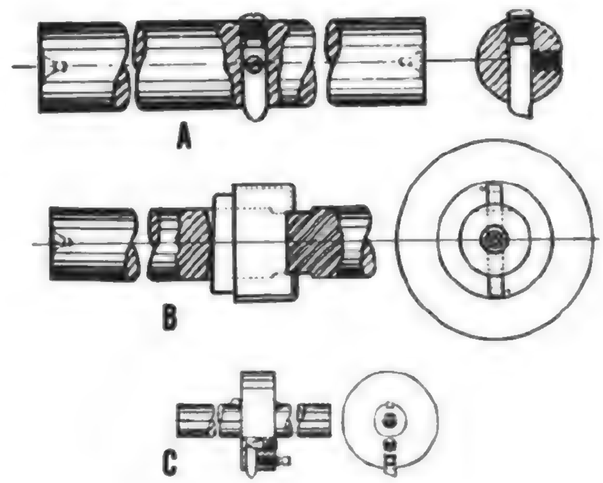
Machining to a shoulder is often done by locating the shoulder with a parting tool. The parting tool is inserted about 1/32 inch back of the shoulder line, and enters the work within 1/32 inch of the smaller diameter of the work. Then the stock may be machined by taking heavy cuts up to the shoulder thus made. Shouldering eliminates detailed measuring and speeds up production.

Figure 18-29 illustrates the method of shouldering. A parting tool has been used at P and the turning tool is taking a cut. It will be unnecessary to waste any time in taking measurements. You can devote your time to rough machining until the necessary stock is removed. Then you can take a finishing cut to accurate measurement.

BORING

Boring is the machining of holes or any interior cylindrical surface. The piece to be bored must have a drilled or cored hole, and the hole must be large enough to insert the tool. The boring process merely enlarges the hole to the desired size or shape. The advantage of boring is that a perfectly true round hole is obtained, and two or more holes of the same or different diameters may be bored at one setting, thus ensuring absolute alignment of the axis of the holes.

It is the usual practice to bore a hole to within a few thousandths of an inch of the desired size and then finish it with a reamer to the exact size.



28.134
Figure 18-30.—Boring bars.

Work to be bored may be held in a chuck, bolted to the faceplate, or bolted to the carriage. Long pieces must be supported at the free end in a center rest.

When the boring tool is fed into the hole in work being rotated on a chuck or faceplate, the process is called single point boring. It is the same as turning except that the cutting chip is taken from the inside. The cutting edge of the boring tool resembles that of a turning tool. Boring tools may be of the solid forged type or the inserted cutter bit type.

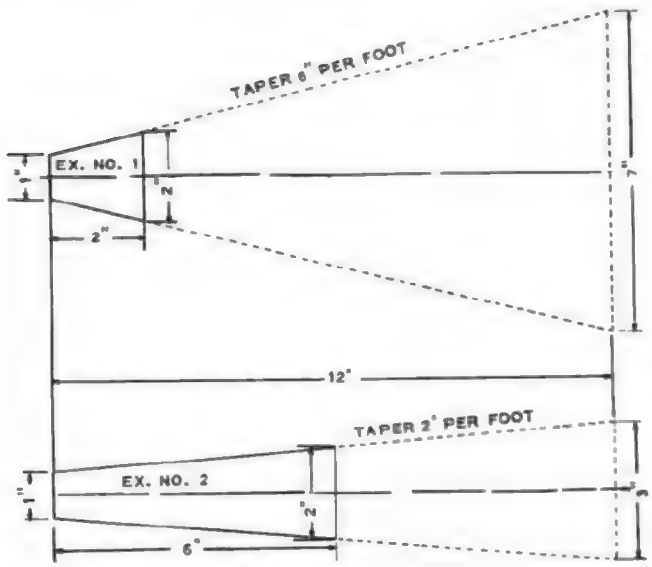
When the work to be bored is clamped to the top of the carriage, a boring bar is held between centers and driven by a dog. The work is fed to the tool by the automatic longitudinal feed of the carriage. Three types of boring bars are shown in figure 18-30.

Note the countersunk center holes at the ends to fit the lathe centers.

Figure 18-30(A) shows a boring bar fitted with a fly cutter held by a headless setscrew. The other setscrew, bearing on the end of the cutter, is for adjusting the cutter to the work.

Figure 18-30(B) shows a boring bar fitted with a two-edged cutter held by a taper key. This is more of a finishing or sizing cutter, as it cuts on both sides and is used for production work.

The boring bar shown in figure 18-30(C) is fitted with a cast-iron head to adapt it for boring work of large diameter. The head is fitted with a fly cutter similar to the one shown in part A of figure 18-30. The setscrew with the tapered point adjusts the cutter to the work.



28.137
Figure 18-31.—Tapers.

TAPERS

The term "taper" may be defined as the gradual lessening of the diameter or thickness of a piece of work toward one end. The amount of taper in any given length of work is found by subtracting the size of the small end from the size of the large end. Taper is usually expressed as the amount of taper per foot of length, or as an angle.

We will take two examples as an illustration.

EXAMPLE 1.—Find the taper per foot of a piece of work 2 inches long: Diameter of small end is 1 inch; diameter of the large end is 2 inches.

The amount of the taper is 2 inches minus 1 inch, which equals 1 inch. The length of the taper is given as 2 inches. Therefore, the taper is 1 inch in 2 inches of length. In 12 inches of length it would be 6 inches. (See fig. 18-31.)

EXAMPLE 2.—Find the taper per foot of a piece 6 inches long. Diameter of small end is 1 inch; diameter of large end is 2 inches.

The amount of taper is the same as problem 1, that is, 1 inch. However, the length of this taper is 6 inches; hence the taper per foot is 1 inch x 12/6 = 2 inches per foot (fig. 18-31).

From the foregoing, it may be seen that the length of a tapered piece is very important in computing the taper. If you bear this in mind when machining tapers you will not go wrong. Using the formula:

$$\text{Taper per foot} = T \times \frac{12}{L},$$

where T represents the amount of taper in length L, both expressed in inches.

Now let us consider the angle of the taper. In a round piece of work, the included angle of the taper is twice the angle that the surface makes with the axis or centerline. In straight turning, it will be recalled that the diameter of a piece is reduced by twice the depth of the cut taken from its surface. For the same reason, the included angle of the taper is twice the angle that the path of the cutting tool makes with the axis or centerline of the piece being turned. There are tables or charts in all machinist's handbooks that give the angles for different amounts of taper per foot.

There are several well-known tapers that are recognized as standards for machines in which they are used. These standards make it possible to make or obtain parts to fit the machine in question without the necessity of detailed measuring and fitting. By designating the name and number of the standard taper being used, the length, the diameter of the small and large ends, the taper per foot, and all other pertinent measurements are immediately obtainable by reference to appropriate tables found in machinist's handbooks.

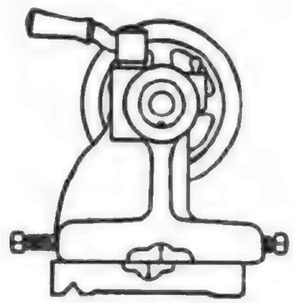
There are three standard tapers with which you should be familiar: (1) the MORSE TAPER (approximately 5/8 inch per foot) used for the taper holes in lathe and drill press spindles and the attachments that fit them, such as lathe centers, drill shanks, etc.; (2) the BROWN & SHARPE TAPER (1/2 inch per foot except No. 10 which is 0.5161 inch per foot) used for milling machine spindle shanks; and (3) the JARNO TAPER (0.6 inch per foot) used by some manufacturers because of its simplicity, it being the only taper that is constant and does not require a table to find the various dimensions pertaining to its parts; e.g.

$$\text{Diameter of large end} = \frac{\text{taper number}}{8}$$

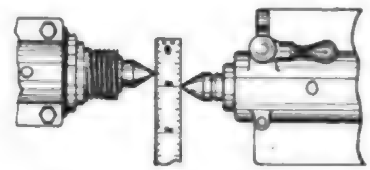
$$\text{Diameter of small end} = \frac{\text{taper number}}{10}$$

$$\text{Length of taper} = \frac{\text{taper number}}{2}$$

The taper for pipe ends, 3/4 inch per foot, is also considered a standard.



28.139X
Figure 18-32.—Tailstock setover for taper turning.



28.140X
Figure 18-33.—Measuring setover for dead center.

Turning Tapers

In ordinary straight turning, the cutting tool moves along a line parallel to the axis of the work, causing the finished job to be the same diameter throughout. If, however, in cutting, the tool moves at an angle to the axis of the work, a taper will be produced. Therefore, to turn a taper, it is necessary either to mount the work in the lathe so the axis upon which it turns is at an angle to the axis of the lathe, or to cause the cutting tool to move at an angle to the axis of the lathe.

There are three methods in common use for turning tapers:

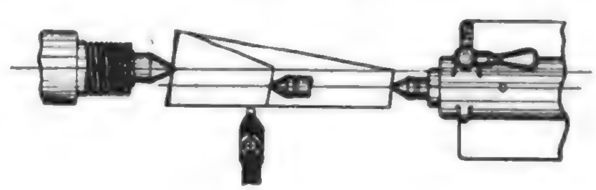
1. SETTING OVER THE TAILSTOCK, which moves the dead center away from the axis of the lathe and hence causes work supported between centers to be at an angle with the axis of the lathe.
2. USING THE COMPOUND REST set at an angle and causing the cutting tool to be fed at the desired angle to the axis of the lathe.
3. USING THE TAPER ATTACHMENT, which also causes the cutting tool to move at an angle to the axis of the lathe.

In the first method, the cutting tool is fed by the longitudinal feed parallel to the lathe axis, but a taper is produced because the work axis is at an angle. In the second and third methods, the work axis coincides with the lathe axis, but a taper is produced because the cutting tool moves at an angle.

SETTING OVER THE TAILSTOCK.—The tailstock top may be moved laterally on its base by means of adjusting screws. In straight turning, you will recall that these adjusting screws were used to align the dead center with the tail center by moving the tailstock to bring it on the centerline. For taper turning, we deliberately move the tailstock off-center, and the amount we move it determines the taper produced. The amount of setover can be approximately set by means of the zero lines inscribed on the base and top of the tailstock as shown in figure 18-32. Then for final adjustment, the setover is measured with a scale between center points as illustrated in figure 18-33.

In turning a taper by this method, the distance between centers is of utmost importance. To illustrate, figure 18-34 shows two very different tapers produced by the same amount of setover of the tailstock, because in one case the length of the work between centers is greater than in the other. THE CLOSER THE DEAD CENTER IS TO THE LIVE CENTER, THE STEEPER THE TAPER PRODUCED.

Suppose it is desired to turn a taper on the full length of a piece 12 inches long with one end having a diameter of 3 inches, and the other end a diameter of 2 inches. The small end is to be 1 inch smaller than the large end; so we set the tailstock over one-half this amount or 1/2 inch. Thus, at one end the cutting tool will be 1/2 inch closer to the center of the work than at the other end; so the diameter of the finished job will be 2 x 1/2 or 1 inch less at the small end. Since the piece is 12 inches long, we have produced a taper of 1 inch per foot. Now, if you wish to produce a taper of 1 inch per foot on a piece only 6 inches long, the small end would be only 1/2 inch less in diameter than the large end, so the tailstock would be set over 1/4 inch



28.141X
Figure 18-34.—Setover of tailstock showing importance of considering length of work.

or one-half of the distance used for the 12-inch length.

From the foregoing, it is seen that the setover is proportional to the length between centers and may be computed by the following formula:

$$S = \frac{T}{2} \times \frac{L}{12}$$

Where: S = setover in inches
T = taper per foot in inches
$\frac{L}{12}$ = length in feet

Remember that L is length of work, in inches, from live center to dead center. If the work is on a mandrel, L is the length of the mandrel between centers.

The setover tailstock method cannot be used for steep tapers because the setover necessary would be too great and the work would not be properly supported by the lathe centers. It is obvious that with setover there is not a true bearing between the work centers and the lathe center points, and that the bearing surface becomes less and less satisfactory as the setover is increased.

After turning a taper by the tailstock setover method, realign the centers for straight turning of your next job.

USING THE COMPOUND REST.—The compound rest is generally used for short, steep tapers. It is set at the angle which the taper is to make with the centerline (that is half the included angle of the taper). The tool is then fed to the work at this angle by means of the compound rest feed screw. The length of taper that can be machined is necessarily short because of limited travel of the compound rest top.

Truing a lathe center is one example of the use of the compound rest for taper work. Other examples are the refacing of an angle type valve disk, the machining of the face of a bevel gear, and similar work. Such jobs are often referred to as working to an angle rather than as taper work.

The graduations marked on the compound rest provide a quick means for setting to the angle desired. When set at zero, the compound rest is perpendicular to the lathe axis. When set at 90° on either side, the compound rest is parallel to the lathe axis.

However, when the angle to be cut is measured from the centerline, the setting of the compound rest corresponds to the complement of that angle-(the complement of an angle is that angle which added to it makes a right angle; that is, angle plus complement = 90°). For example, to machine a 50° included angle (25° angle with centerline), the compound rest is set at 90° −25° or 65°.

When a very accurate setting of the compound rest is to be made to a fraction of a degree, for example, run the carriage up to the faceplate and set the compound rest with a vernier bevel protractor set to the required angle. The blade of the protractor is held on the flat surface of the faceplate, and the stock is held against the finished side of the compound rest.

USING THE TAPER ATTACHMENT.—For turning and boring long tapers with accuracy, the taper attachment is indispendable. It is especially useful in duplicating work; identical tapers can be turned and bored with one setting of the taper guide bar.

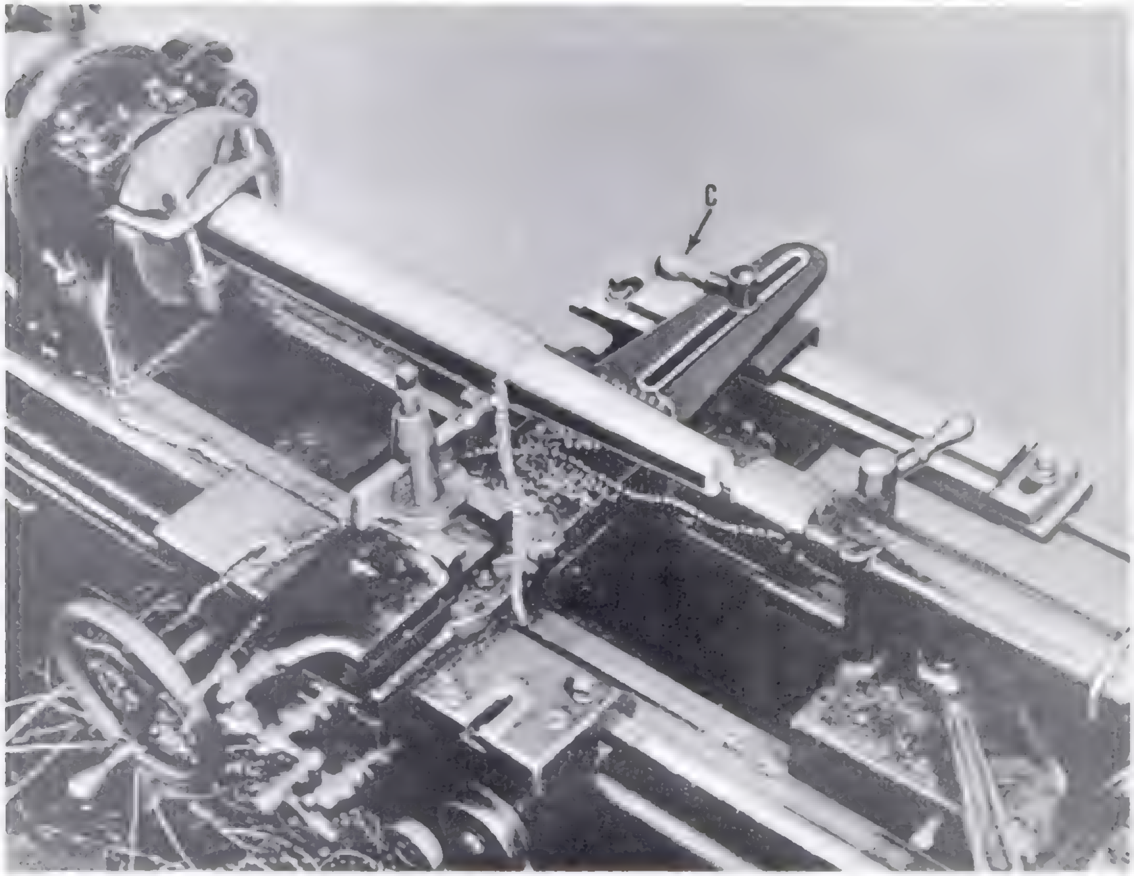
The guide bar is set at an angle to the lathe axis corresponding to the taper desired. By means of a shoe which slides on the guide bar as the carriage moves longitudinally, the tool cross-slide is moved laterally. The resultant movement of the cutting tool is along a line that is parallel to the guide bar, and therefore a taper is produced whose angular measurement is the same as that set on the guide bar. The guide bar is graduated in degrees at one end, and in inches per foot of taper at the other end to facilitate rapid setting.

When preparing to use the taper attachment, run the carriage up to the approximate position of the work to be turned. Set the tool on line with the centers of the lathe. Then bolt or clamp the holding bracket to the ways of the bed (the attachment itself is bolted to the back of the carriage saddle) and tighten clamp C, figure 18-35. The taper guide bar now controls the lateral movement of the cross-slide. Set the guide bar for the taper desired and the attachment is ready for operation. The final adjustment of the tool for size must be made by means of the compound rest feed screw, since the crossfeed screw is inoperative.

Taper Boring

Taper boring may be accomplished only by the use of the compound rest or the taper attachment.

The rules that are applicable to outside taper turning also apply to the boring of tapered holes. The cutting point of the tool is placed on center and, if the taper attachment is used, care must be exercised to eliminate the backlash of the slide fittings so that the hole will not be bored straight at the start. Measurement of the size



28.143X
Figure 18-35.—Turning a taper using taper attachment.

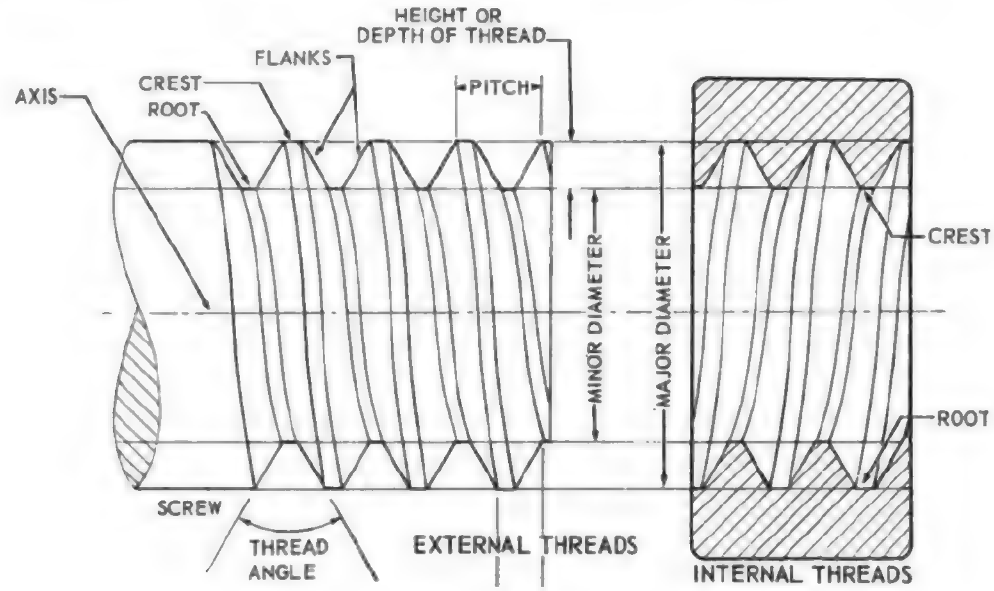
and taper of the hole is generally made with a taper plug gage by the cut and try method. After a cut or two has been taken, the bore is cleaned, the gage rubbed lightly with chalk, inserted in the hole and twisted slightly to cause the chalk to show where the gage is bearing. Any necessary corrections may then be made and the boring continued until the taper is brought to size. A very light application of prussian blue to the gage will give better results than chalk for accurate work.

28.144X
Figure 18-36.—Morse taper socket and plug gage.

When making a blind tapered hole, such as may be required in drill sockets, it is best to drill the hole carefully to the correct depth with a drill of the same size as specified for the small end of the hole. This gives the advantage of boring to the right size without the removal of metal at the extreme bottom of the bore, which is rather difficult, particularly in small, deep holes.

For turning and boring tapers the tool cutting edge should be set exactly at the center of the work. That is, set the point of the cutting edge even with the height of the lathe centers.

In testing the taper on a piece of work that is to fit a spindle and is nearly finished, make a chalk mark along the element or side of the taper piece. Place the work in the taper hole it is to fit and turn carefully by hand. Then remove the work, and the chalk mark will show



28.145
Figure 18-37.—Screw thread nomenclature.

where the taper is bearing. If it is a perfiect fit, it will indicate along the entire line of the chalk mark. If it is not, it will show where the adjustment is needed. Make the adjustment, take another light cut, and test again. Be sure the taper is correct before turning to the finished diameter.

Figure 18-36 shows a Morse standard taper plug and a taper plug and a taper socket gage. They not only give the proper taper, but also show the proper distance that the taper should enter the spindle.

SCREW THREADS

The thread forms you will be working with most are V-form threads, Acme threads, and square threads. Each of these thread forms is used for specific applications. V-form threads are commonly used on fastening devices such as bolts and nuts as well as on machine parts. Acme screw threads are generally used for transmitting motion such as that between the lead screw and lathe carriage. Square threads are used to increase mechanical advantage and to provide good clamping ability as in the screw jack or vise screw.

Terminology

There are several terms used in describing screw threads and screw thread systems which you must know before you can calculate and machine screw threads. Figure 18-37 illustrates the application of some of the following terms:

External Thread.—A thread on the external surface of a cylinder.

Internal Thread.—A thread on the internal surface of a hollow cylinder.

Right-Hand Thread.—A thread which, when viewed axially, winds in a clockwise and receding direction.

Left-Hand Tread. —A thread which, when viewed axially, winds in a counterclockwise and receding direction.

Lead.—The distance a threaded part moves axially in a fixed mating part in one complete revolution.

Pitch.—The distance between corresponding points on adjacent threads.

Single Thread.—A single (single start) thread having the lead equal to the pitch.

Multiple Thread.—A multiple (multiple start) thread has a lead which is equal to the pitch multiplied by the number of starts.

Class of Threads.—Classes of threads are distinguished from each other by the amount of tolerance or tolerance and allowance specified.

Thread Form.—The axial plane profile of a thread for a length of one pitch.

Flank.—The side of the thread.

Crest.—The top of the thread (bounded by the major diameter on external threads; by the minor diameter on internal threads).

Root.—The bottom of the thread (bounded by the minor diameter on external threads; by the major diameter on internal threads).

Thread Angle.—The angle formed by adjacent flanks of a thread.

Major Diameter.—The diameter of a cylinder that bounds the crest of an external thread or the root of an internal thread.

Minor Diameter.—The diameter of a cylinder that bounds the root of an external thread or the crest of an internal thread.

Height of Thread.—The distance from the crest to the root of a thread measured perpendicular to the axis of the threaded piece (also called depth of thread).

Slant Depth.—The distance from the crest to the root of a thread measured along the angle forming the side of the thread.

Thread Series.—Groups of diameter pitch combinations which are distinguished from each other by the number of threads per inch to a specific diameter. The common thread series are the coarse series and the fine series.

Forms of Threads

V-FORM THREADS.—The two forms of V-threads are the American National and the American Stantard. All of these threads have a 60° included angle between their sides.

The external American Standard thread has slightly less depth than the external American National thread but is otherwise similar. The American Standard thread is actually a modification of the American National thread. This modification was made so that a unified series of threads, which permits interchangeability of standard threaded fastening devices manufactured in the United States, Canada, and the United Kingdom, could be included in the threading system used in the United States. The Naval Ship Systems Command and naval procurement activities use American Standard threading system specifications whenever possible; this system is recommended for use by all naval activities.

To cut an ANS thread, you need to know (1) the pitch of the thread, (2) the straight depth of the thread, (3) the slant depth of the thread, and (4) the width of the flat at the root of the thread. The pitch of a thread is the basis for calculating all other dimensions and is equal to 1 divided by the number of threads per inch. Twice the straight depth of an internal thread subtracted from the outside diameter of the externally threaded part is the basis for determining the bore diameter of a mating part to be threaded internally. When the thread cutting tool is fed into the workpiece at one-half of the included angle of the thread, the slant depth is the dimension necessary to determine how far to feed the tool into the work. The point of the threading tool must have a flat equal to the width of the flat at the root of the thread (external or internal thread, as applicable). If the flat at the point of the tool is too wide, the resulting thread will be too thin if the cutting tool is fed in the correct amount. If the flat is too narrow, the thread will be too thick.

The following formulas will provide you with the information you need to know for cutting ANS threads:

AMERICAN NATIONAL THREAD.

Pitch = 1 ÷ number of threads per inch = $\frac{1}{n}$

Depth of external thread = 0.64952 x pitch = 0.64952p

Depth of internal thread = 0.541266 x pitch = 0.541266p

Width of flat at point of tool for external and internal threads = 0.125 x pitch = 0.125p

Slant depth of external thread = 0.750 x pitch = 0.750p

Slant depth of internal thread = 0.625 x pitch = 0.625p

AMERICAN STANDARD THREAD.

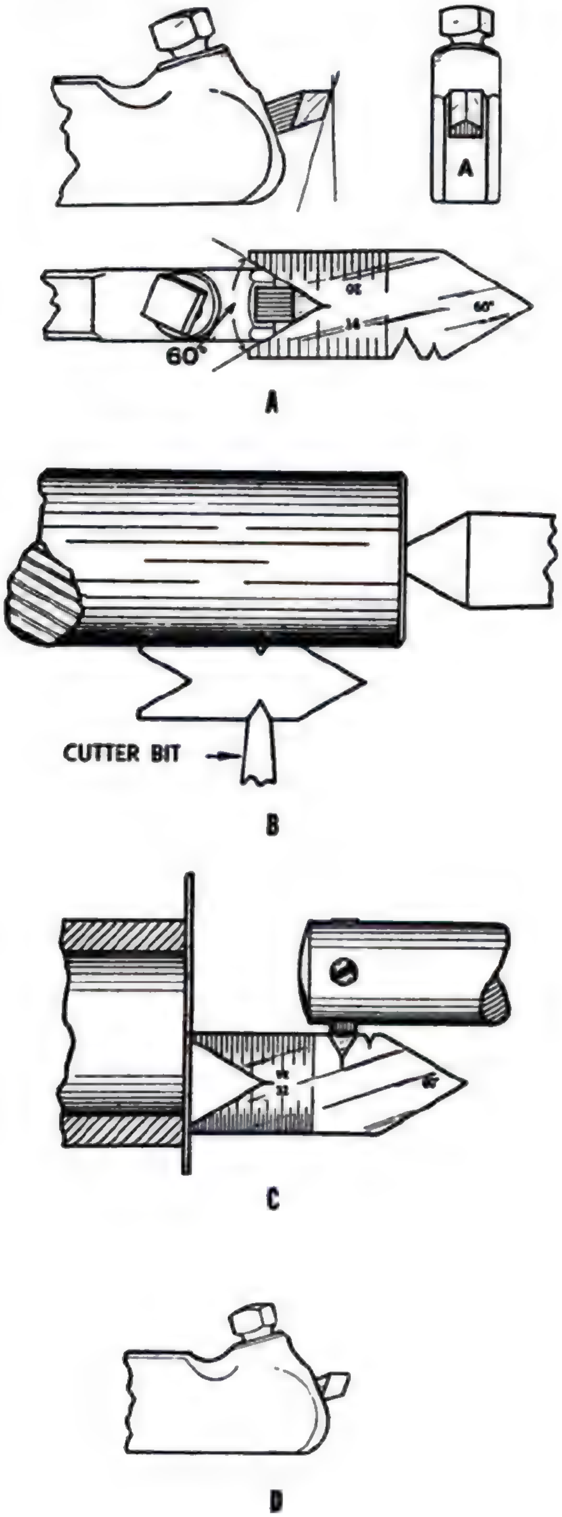
Pitch = 1 ÷ number of threads per inch = $\frac{1}{n}$

Depth of external thread = 0.61343 x pitch = 0.61343p

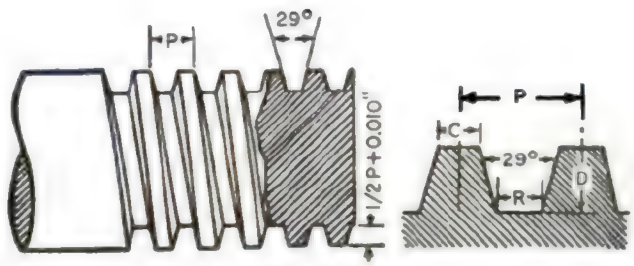
Depth of internal thread = 0.541266 x pitch = 0.541266p

Width of flat at point of tool for external threads = 0.166 x pitch = 0.166p

Width of flat at point of tool for internal threads = 0.125 x pitch = 0.125p



28.146X
Figure 18-38.—Threading tool setup for ANS threads.



FORMULAS

PITCH (P) = $\frac{1}{\text{No. Threads per inch}}$

DEPTH (D) = 1/2 P + 0.010"

SLANT DEPTH = 0.516P + 0.010"

CREST (C) = 0.3707 P

ROOT (R) = 0.3707 P − 0.0052"

28.147X
Figure 18-39.—Acme thread and formulas.

Slant depth of external thread = 0.708 x pitch = 0.708p

Slant depth of internal thread = 0.625 x pitch = 0.625p

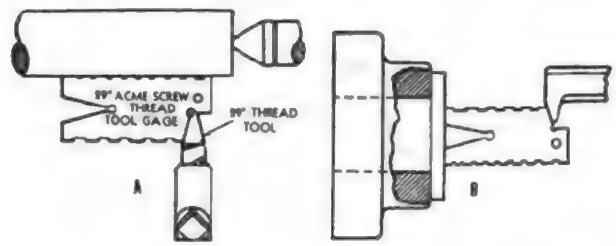
To produce the correct thread profile, the cutting tool must be accurately ground to the correct angle and contour. Also the cutting tool must be set in the correct position. Figure 18-38 shows how a tool must be ground and set.

The point of the tool must be ground to an angle of 60°, as shown in A of figure 18-38. A center gage or a thread-tool gage is used for grinding the tool to the exact angle required. The top of the tool is usually ground flat, with no side rake or back rake. However, for cutting threads in steel, side rake is sometimes used.

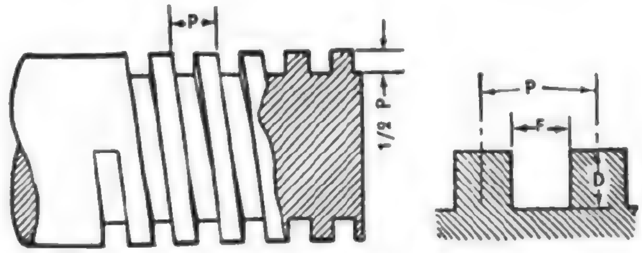
The threading tool must be set square with the work, as shown in B and C of figure 18-38. The center gage is used to adjust the point of the threading tool and if the tool is carefully set, a perfect thread will result. Of course, if the threading tool is not set perfectly square with the work, the angle of the thread will be incorrect.

For cutting external threads, the top of the threading tool should be placed exactly on center as shown in D of figure 18-38. Note that the top of the tool is ground flat and is in exact alignment with the lathe center. This is necessary to obtain the correct angle of the thread.

Size of the threading tool for cutting an internal thread is important. The tool head must be small enough to be backed out of the thread and still leave enough clearance to be drawn from the threaded hole without injuring the thread.



28.148X
Figure 18-40.—Use of Acme thread tool gage.



FORMULAS

$$\text{PITCH (P)} = \frac{1}{\text{No. Threads per Inch}}$$

$$\text{DEPTH (D)} = P \times 0.500''$$

$$\text{SPACE (F)} = P \times 0.500''$$

28.149X
Figure 18-41.—Square thread and formulas.

However, the boring bar which holds the threading tool for internal threading should be as large in diameter and as short as possible to prevent springing.

THE ACME SCREW THREAD.—The Acme screw thread is used on valve stems, the lead screw of a lathe, and other places where a strong thread is required. The top and bottom of the threads are similar to a square thread in that they are flat. The sides of the thread have an included angle of 29° (fig. 18-39).

Parts A and B of figure 18-40 show the method of setting an Acme threading tool for cutting an external and internal Acme thread, respectively. Note that a 29° Acme thread gage is used in the same manner as the center gage was used for ANS threads. Adjust the cutting edge of the tool to line it up exactly with the beveled edge of the gage.

In cutting an Acme thread, there should be a clearance of 0.010 inch between the top of the thread of the screw and the bottom of the thread of the nut in which it fits.

THE SQUARE THREAD.—The square thread (fig. 18-41) is used where heavy threads are required, such as in jack screws, press screws, and feed screws. It is used for much the same purpose as the Acme thread, which is used in many places where the square thread was formerly used. The disadvantage of square threads is that the straight sides eliminate sideplay adjustment.

The cutting edge width of the tool for cutting square screw threads is exactly one-half the pitch, but the width of the edge of the tool for threading nuts is from 0.001 inch to 0.003 inch larger. This permits a sliding fit on the screw.

The threading tool for cutting square threads is set square with the work. Since the edge of the tool is square, it is only necessary to adjust the edge to the surface of the work.

The clearance between the top of the thread of the screw and that of the bottom of the thread of the nut should be about 0.005 inch to 0.006 inch for each inch of thread diameter.

Cutting Screw Threads

Cutting screw threads on the lathe is accomplished by connecting the headstock spindle of the lathe with the lead screw by a series of gears so that a positive carriage feed is obtained, and the lead screw is driven at the required speed with relation to the headstock spindle. The gearing between the headstock spindle and lead screw may be arranged so that any desired pitch of the thread may be cut. For example, if the lead screw has 8 threads per inch and the gears are arranged so that the headstock spindle revolves four times while the lead screw revolves once, the thread cut will be four times as fine as the thread on the lead screw, or 32 threads per inch. By means of the quick-change gear box, the proper gearing arrangement can be made quickly and easily by placing the levers as indicated on the index plate for the thread desired.

When the lathe is set up to control the carriage movement for cutting the desired thread pitch, the next consideration is shaping the thread. The cutting tool is ground to the shape required for the form of the thread to be cut, that is V, Acme, square, etc. The depth of the thread is obtained by adjusting the cross slide.

MOUNTING WORK IN THE LATHE.—When mounting work between lathe centers for cutting screw threads, be sure the lathe dog is securely attached before starting to cut the thread. If the dog should slip, the thread will be ruined. Never remove the lathe dog from the work until the

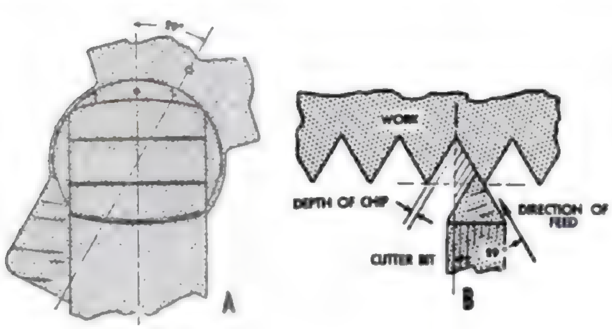
thread has been completed. If it is necessary to remove work from the lathe before the thread is completed, be sure that the lathe dog is replaced in the same slot of the driving plate.

When threading work in the lathe chuck, be sure the chuck jaws are tight and the work is well supported. The chuck must be tight enough on the spindle to prevent unscrewing when the lathe is reversed. Never remove the work from the chuck until the thread is finished.

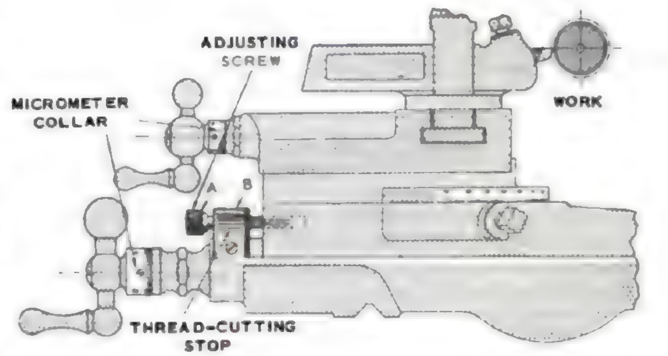
When threading long slender shafts, use a follower rest. The center rest must be used for supporting one end of long work that is to be threaded on the inside.

POSITION OF COMPOUND REST FOR CUTTING SCREW THREADS.—Ordinarily on threads of fine lead, the tool is fed straight into the work on successive cuts. For coarse threads, it is better to set the compound rest at one-half of the included angle of the thread and feed in along the side of the thread. For the last few finishing cuts, the tool should be fed straight in with the crossfeed of the lathe to make a smooth, even finish on both sides of the thread.

When cutting ANS threads and when maximum production is desired, it is customary to place the compound rest of the lathe at an angle of 29°, as shown in part A of figure 18-42. When the compound rest is set in this position, and the compound-rest screw is used for ajusting the depth of cut, most of the metal is removed by the left side of the threading tool (part B of fig. 18-42). This permits the chip to curl out of the way better than if the tool is fed straight in, and prevents tearing the thread. Since the angle on the side of the threading tool is 30°, the right side of the tool will shave the thread smooth and produce a better finish; although it does not remove enough metal to interfere with the main cut, which is taken by the left side of the tool.



28.150X
Figure 18-42.—Compound rest set at 29°.



28.151X
Figure 18-43.—Adjustable thread-cutting stop mounted on carriage saddle (clamped to dovetail).

USING THE THREAD-CUTTING STOP.—On account of the lost motion caused by the play necessary for smooth operation of the change gears, lead screw, half-nuts, etc., the thread-cutting tool must be withdrawn quickly at the end of each cut. If this is not done, the point of the tool will dig into the thread and may be broken off.

To reset the tool accurately for each successive cut, and to regulate the depth of the chip, the thread-cutting stop is useful.

First, set the point of the tool so that it just touches the work, then lock the thread-cutting stop and turn the thread-cutting stop screw A (fig. 18-43) until the shoulder is tight against stop B (fig. 18-43). When ready to take the first cut, run the tool rest back by turning the crossfeed screw to the left several times and move the tool to the point where the thread is to start. Then turn the crossfeed screw to the right until the thread-cutting stop screw strikes the thread-cutting stop. The tool is now in the original position, and turning the compound-rest feed screw in 0.002 inch or 0.003 inch will place the tool in a position to take the first cut (fig. 18-43).

For each successive cut after the carriage is returned to its starting point, the tool can be reset accurately to its previous position. Turn the crossfeed screw to the right until the shoulder of screw A strikes stop B. Then the depth of the next cut can be regulated by adjustment of the compound rest feed screw as for the first cut.

For cutting an internal thread, the adjustable thread-cutting stop should be set with the head of the adjusting screw on the inside of the stop. In this case, the tool is withdrawn by moving it toward the center or axis of the lathe.

The micrometer collar on the crossfeed screw may be used in place of the thread-cutting stop, if desired.

To do this, first bring the point of the threading tool up so that it just touches the work; then adjust the micrometer collar on the crossfeed screw to zero. All adjustments for obtaining the desired depth of cut should be made with the compound-rest screw. Withdraw the tool at the end of each cut by turning the crossfeed screw to the left one complete turn; return the tool to the starting point and turn the crossfeed screw to the right one turn, stopping at zero. The compound rest feed screw may then be adjusted for any desired depth.

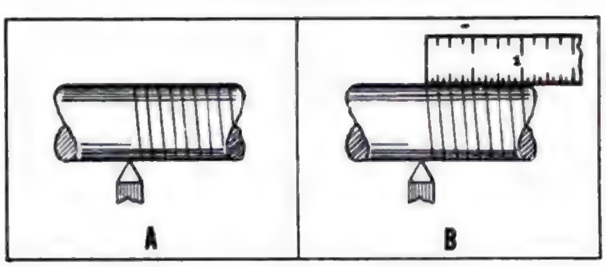
ENGAGING THE THREAD FEED MECHANISM.—When threads are being cut on a lathe, the half-nuts are clamped over the lead screw to engage the threading feed and released at the end of the cut by means of the threading lever. The threading dial (illustrated in fig. 18-15) provides a means for determining the time to engage the half-nuts so that the cutting tool follows the same path during each cut. When an index mark on the threading dial is aligned with the witness mark on its housing, the half-nuts may be engaged. For some thread pitches however, the half-nuts may be engaged only when certain index marks are aligned with the witness mark. On most lathes the half-nuts can be engaged as follows:

For all even-numbered threads per inch, close the half-nuts at any line on the dial.

For all odd-numbered threads per inch, close the half-nuts at any numbered line on the dial.

For all threads involving one-half of a thread in each inch, such as 11 1/2, close the half-nuts at any odd-numbered line.

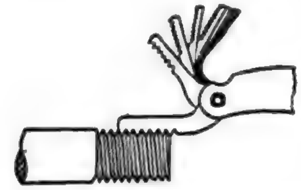
CUTTING THE THREAD.—After setting up the lathe, as explained previously, take a very light trial cut just deep enough to scribe a line on the surface of the work, as shown in part A of figure 18-44. The purpose of this trial cut is to be sure that the lathe is arranged for cutting the desired pitch of thread.



28.152X
Figure 18-44.—The first cut.

To check the number of threads per inch, place a rule against the work, as shown in part B of figure 18-44, so that the end of the rule rests on the point of a thread or on one of the scribed lines. Count the scribed lines between the end of the rule and the first inch mark, and this will give the number of threads per inch.

It is quite difficult to count accurately fine pitches of screw threads, as described above. A screw pitch gage used as illustrated in figure 18-45 is very convenient for checking the finer screw threads. This gage consists of a number of sheet metal plates in which are cut the exact form of threads of the various pitches and each plate is stamped with a number indicating the number of threads per inch for which it is to be used.

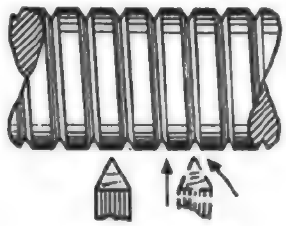


28.153X
Figure 18-45.—Screw pitch gage.

Final check for both diameter and pitch of the thread may be made with the nut that is to be used or with a ring thread gage, if one is available. The nut should fit snugly without play or shake but should not bind on the thread at any point.

RESETTING THE TOOL.—If the thread-cutting tool needs resharpening or gets out of alignment, or if you are chasing the threads on a previously threaded piece, you must reset the tool so that it will follow the original thread groove. This may be done by using the compound-rest feed screw and crossfeed screw to jockey the tool to the proper position, by disengaging the change gears and turning the spindle until the tool is positioned properly, or by loosening the lathe dog (if used) and turning the work until the tool is in proper position with the thread groove. In either case the micrometer collars on the crossfeed screw and compound rest screw will usually have to be reset.

Before adjusting the tool in the groove, use the appropriate thread gage to set the tool square with the workpiece. Then with the tool a few

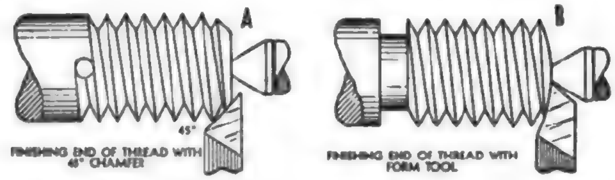


28.154X
Figure 18-46.—Tool must reset to original groove.

thousandths of an inch away from the workpiece, start the machine and engage the threading mechanism. When the tool has moved to a position such as shown in figure 18-46, stop the lathe without disengaging the thread mechanism.

The most practical and commonly used method for resetting a threading tool for machining angular form threads is the compound rest and crossfeed positioning method. By adjusting the compound rest slide forward or backward the tool is moved parallel to the axis of the work as well as toward or away from the work. When the point of the tool coincides with the original thread groove (see alternate view of tool in fig. 18-46), the crossfeed screw is used to bring the tool point directly into the groove. When a good fit between the cutting tool and thread groove is obtained, the micrometer collar on the crossfeed screw is set on zero and the micrometer collar on the compound rest feed screw is set to the depth of cut previously taken or to zero as required. (Note: Be sure that the thread mechanism is engaged and the tool is set square with the work before adjusting the position of the tool along the axis of the workpiece.)

If it is inconvenient to use the compound rest for readjusting the threading tool, the lathe dog



28.155X
Figure 18-47.—Finishing the end of a threaded piece.

(if used) may be loosened; turn the work so that threading tool will match the groove, and tighten the lathe dog. If possible, however, avoid the necessity of doing this.

Another method that is sometimes used, is to disengage the reverse gears or the change grears; turn the headstock spindle until the point of the threading tool enters the groove in the work, and then engage the gears.

FINISHING THE END OF A THREADED PIECE.—The end of a thread may be finished by any one of several methods. The 45° chamfer on the end of a thread, as shown in part A of figure 18-47, is commonly used for bolts, and cap screws. For machined parts and special screws, the end is often finished by rounding with a forming tool, as shown in part B of figure 18-47.

It is difficult to stop the threading tool abruptly, so some provision is usually made for clearance at the end of the cut. In part A of figure 18-47, a hole has been drilled at the end of the thread, and in part B, a neck or groove has been cut around the shaft. The groove is preferable, as the lathe must be run very slowly in order to obtain satisfactory results with the drilled hole.

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